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FARMING SYSTEMS IN THE AFRICAN SAVANNA

A Selective Review of Literature

by

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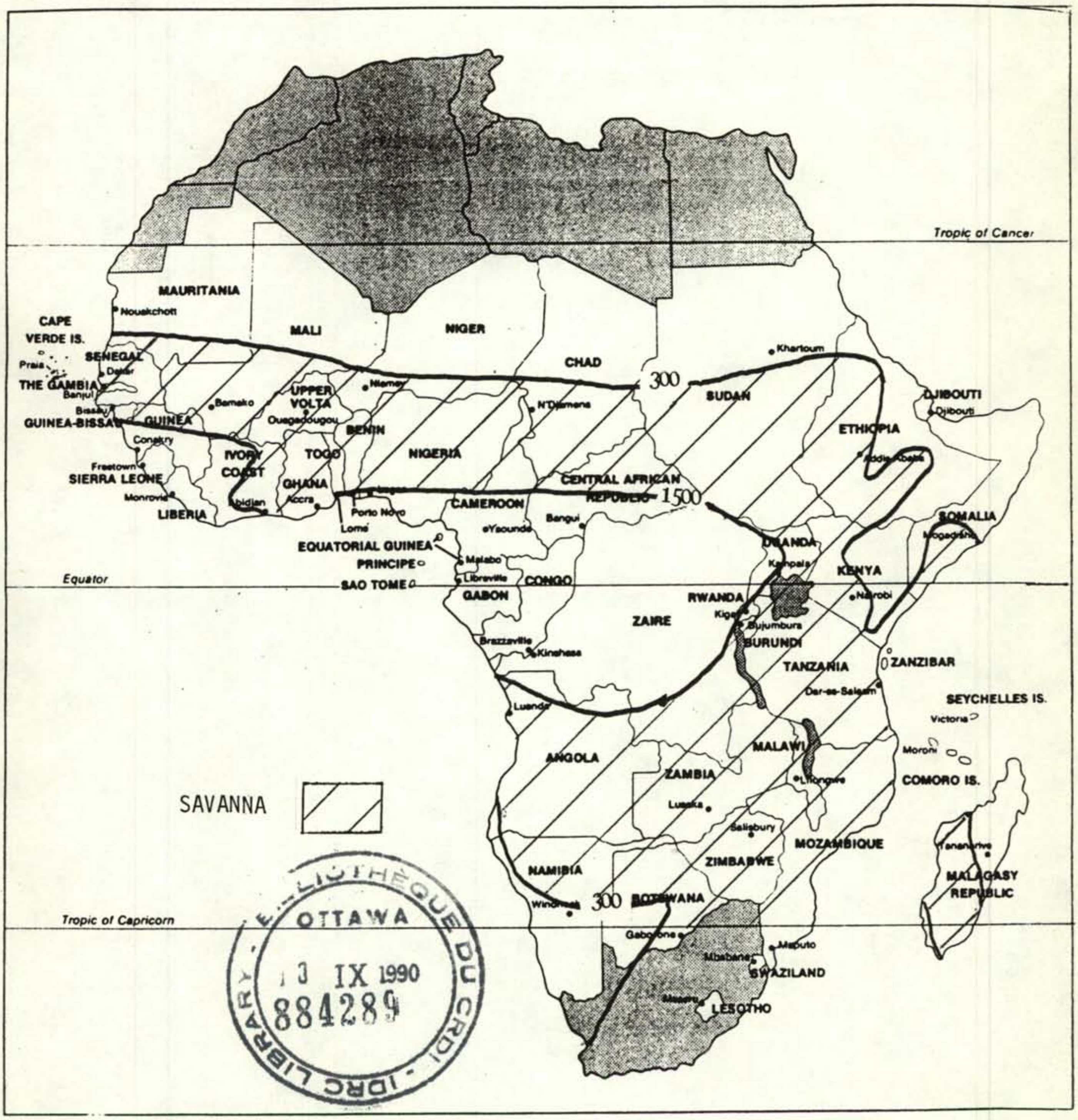

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Chapter 1. INTRODUCTION

Africa is perhaps the continent that is changing most rapidly at the present time. With the exception of Ethiopia and Liberia, all the other 43 countries of tropical Africa have achieved independence during the last 30 years. These young states encompass an enormous diversity of environmental, economic, social, and political conditions. They contain some 800 different ethnic and linguistic groups making up a total population of over 400 million people.

The net rate of population increase in Africa is now the highest in the world, at 3.2 % per year. Also Africa is the only continent where population growth rates are still increasing, as the rates started to decline in Asia and Latin America in the 1960's.

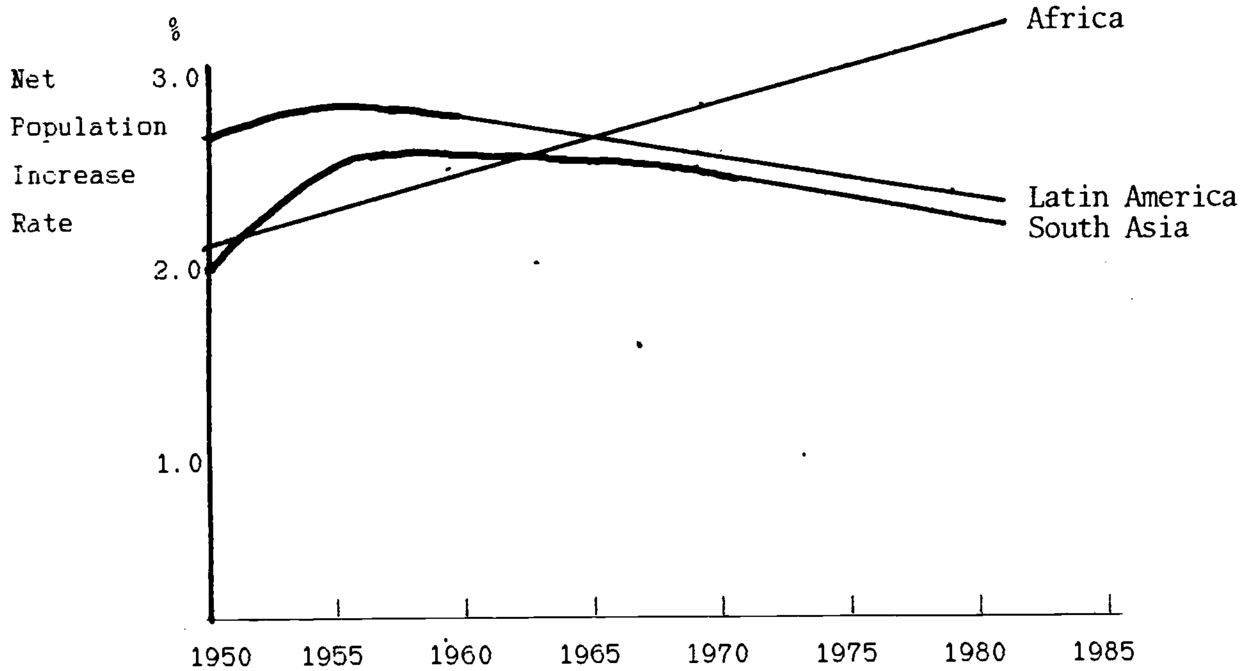


Fig 1. Net Population Increase Rates in Africa, South Asia, and Latin America. (Derived from McNamara 1985).

At the present increase rate of 3.2 % per year in Africa, the population will double in 22 years , quadruple in 44 years, and increase eight-fold in 66 years.

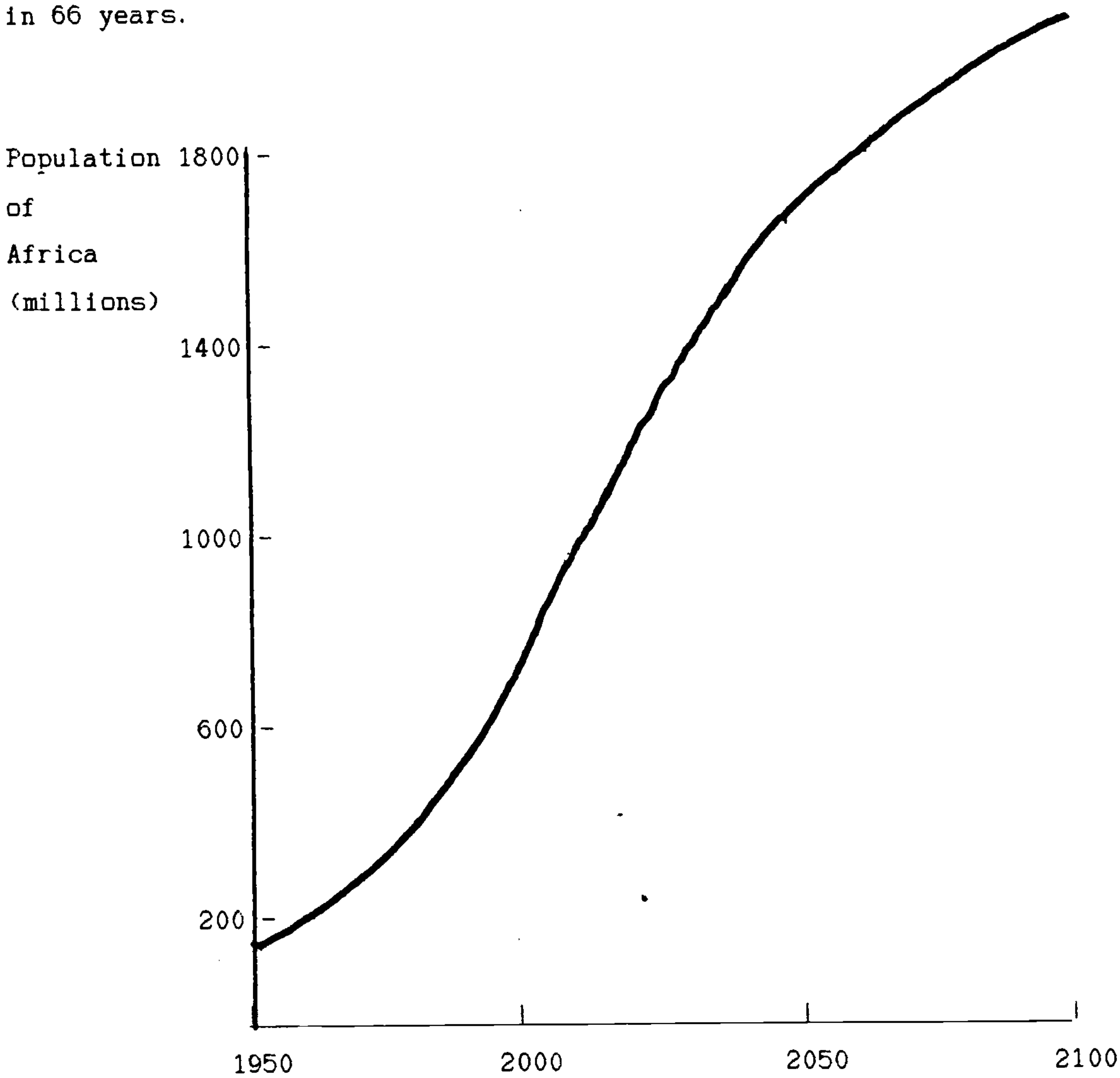


Fig 2. Africa - Projected Population Increase, 1950-2100.

This paper considers the possibility that the critical problem in Africa is that although African farming systems are changing and adapting to increasing population pressures, in most areas they are not changing fast enough. The cultivator's response to declining soil fertility appears to be to attempt to enlarge his cultivated area, even the vegetative cover on the soil surface is depleted, allowing accelerated erosion to occur, so that a progressive decline in soil fertility and an increase in erosion damage take place. Eventually the soil productivity may decline to a low level, or even to near zero.

If this happens, the cultivator may try to respond in one of two ways. Either he may follow the traditional shifting cultivator's path by searching for more fertile land elsewhere, or he may seek to intensify his farming practices by simple soil conservation methods, the use of manure and fertilizers, and by other techniques that may conserve and build up soil fertility. Unfortunately, at present the main response of African cultivators appears to be the former, but since fertile land is becoming increasingly scarce, the search is becoming more and more difficult, and increasing numbers of the displaced people in many areas appear to end up in city slums, or even to starve.

1.1. The African Savanna.

The world's savannas lie between the equatorial rainforests and the deserts of the sub-tropics. Worldwide they cover about one quarter of the earth's surface. The term 'savanna' is in wide general use to describe landscapes characterized by vegetation types ranging from pure grassland to dense woodland, with the presence of a more or less continuous ground layer of grasses beneath or between the trees as the one common denominator. As used here, the term mainly corresponds to the African part of the geographical entity sometimes described as the Intermediate Tropical or Savanna Zone, which is defined as that part of the tropical world that experiences a dry season of 2.5 to 7.5 months duration (Harris 1980, p 3).

However, Phillips (1959) includes semi-arid areas with dry seasons of up to 10 months duration, as part of the African savanna, and the term is used in this sense here. Although it is difficult to define the boundaries of the African savanna precisely, it has been estimated that it occupies over 12 million km2 and covers nearly 60% of tropical Africa (Okigbo 1986, p 95). It includes all or parts of nearly all the 45 countries of tropical Africa. The map (Fig 3) shows the approximate extent of the savanna.

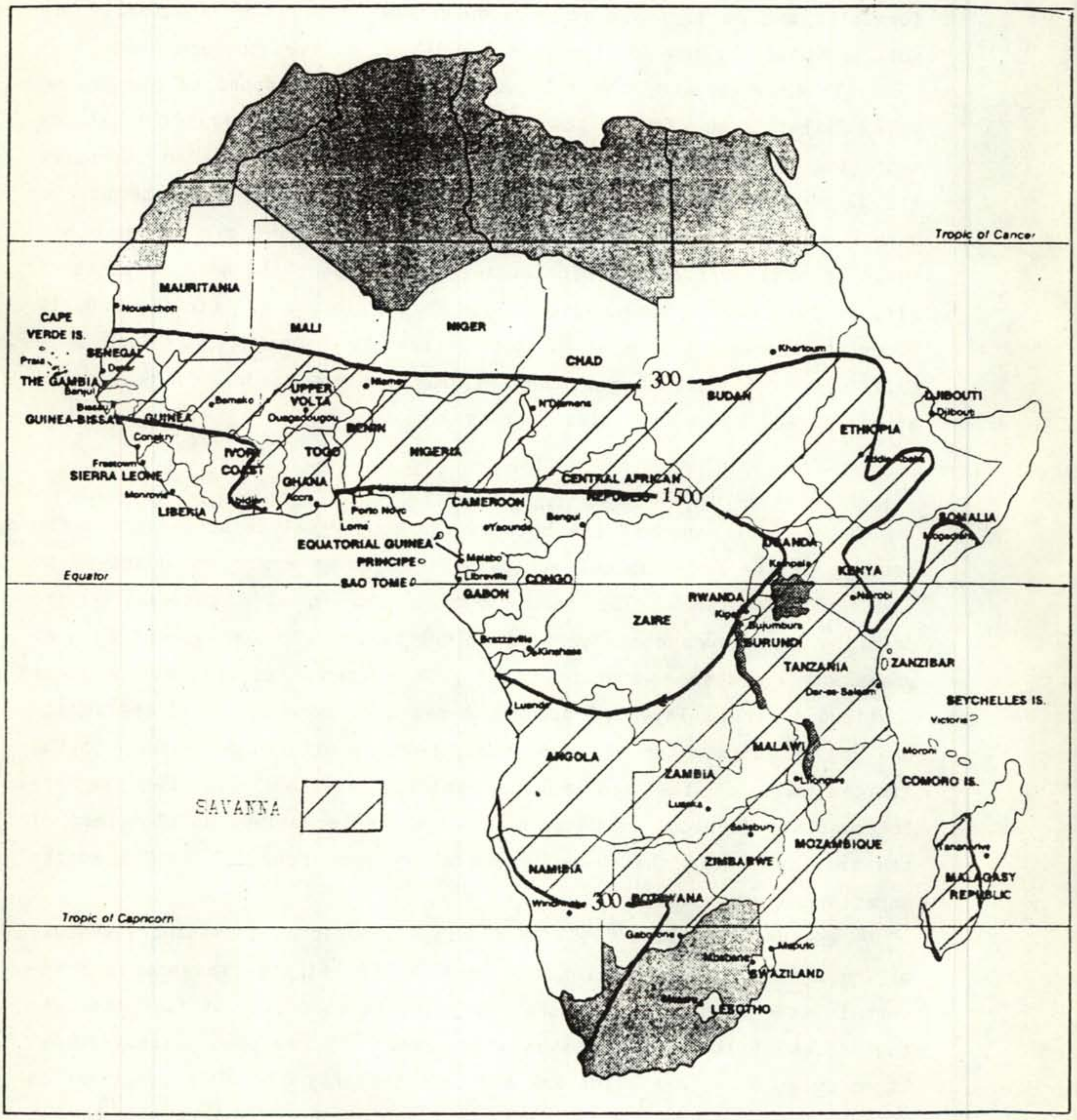


Fig 3. The African savanna.

The savanna zone has been selected for study because it is widely considered to be the zone at greatest risk of declining agricultural production at the present time, and parts of it have been seriously affected by drought and food shortages in recent years. At the same time, the parts of the savanna which receive adequate rain have an enormous potential for the expansion of rainfed agricultural production (Higgins et al. 1982).

1.2. Man-managed Ecosystems

Farms can be considered as ecosystems managed by farmers, so agriculture is the study of man-managed ecosystems. In his classic work on tropical farming systems, Ruthenberg (1980, p2) points out that a farm is both an ecosystem and an independent unit of economic activity, and it is but one system, albeit an important one, among many rural systems. He further suggests that.-

> "Farmers use land which originally was part of a natural system, and most ecological systems untouched by man show a 'zonal' type of vegetation which is typical for the given natural conditions and which is close to a 'steady state'..........Natural systems, however are unproductive in terms of human objectives. The basic principle of farming is to change the natural system into one which produces more of the goods desired by man. The man-made system is an artificial construction which requires continous economic inputs obtained from the environment to maintain its output level. Farming thus implies the abolition of an unproductive 'steady state' in favour of a man-created, more productive but unstable 'state', and much of the farm input (tillage, fertilizers, weeding etc.) is nothing but an effort to prevent the new state from declining towards an unproductive low-level steady state".

After discussing various ways of classifying farming systems, Ruthenberg selected a classification according to the intensity of the rotation, for the purposes of his study.

1.3. Ring Cultivation

Pelissier (1966, p. 474) gives a generalized view of a Senegalese village (Fig 4), which can also be taken to represent villages or farms throughout the savanna (Ruthenberg 1980, p 77).

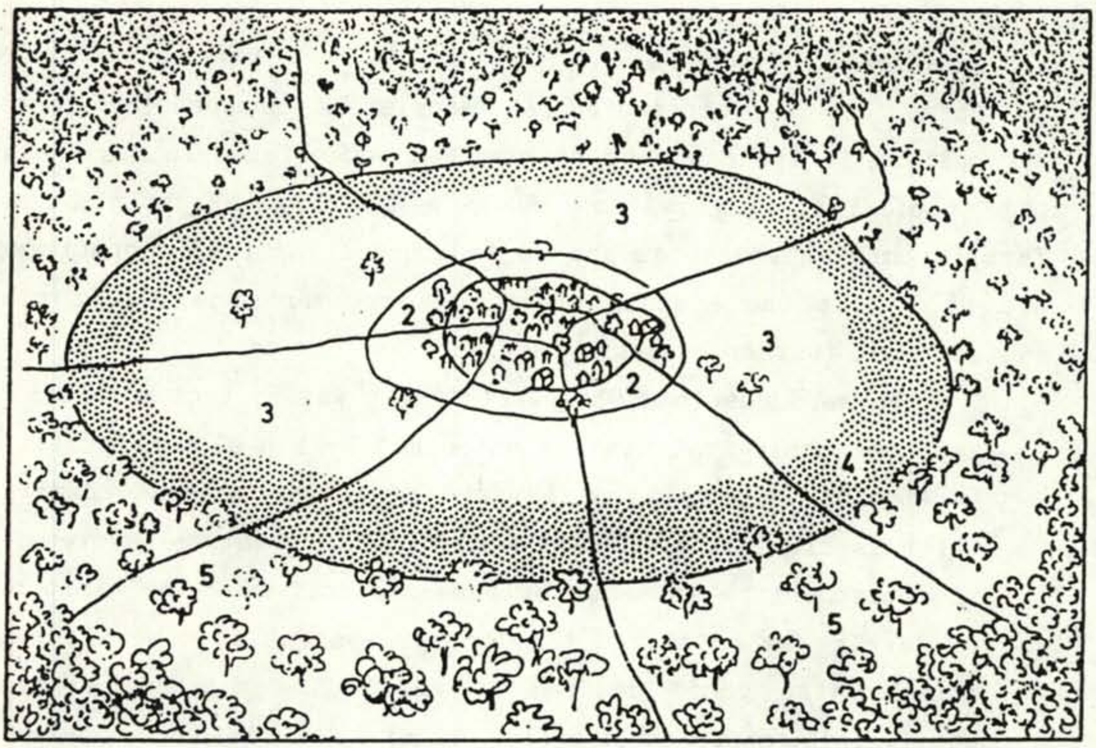


Fig 4. A generalized diagram of a Senegal village, showing ring cultivation (After Pelissier 1966).

This figure indicates how the intensity of cropping decreases in concentive circles or rings from the land immediately around the house to the peripheral fields. The houses in the centre of the village(1) are surrounded by a limited area of permanently cultivated 'garden' land (2) in which a high state of soil fertility is maintained by animal droppings, household refuse and ashes. Fruit trees provide shade and food and also protect the soil. The next area of land surrounding the village often has reduced fertility due to over-cropping, without sufficient addition of materials such as manure to maintain fertility(3). The area around this (4) may be more fertile because of less intensive use and longer fallows, while the surrounding forest or bush may only be used on an intermittent shifting cultivation basis(5).

An example of a similar village in Mali is described later (p).

1.4. Intensification.

It is of considerable interest that Ruthenberg (1980, p 358) outlines the process of intensification of tropical farming systems as passing from shifting systems through fallow systems to permanent upland systems, sometimes with perennial crops and irrigation. In Pelissier's diagram, this is the same as the progression from the shifting cultivation area far from the village, to the permanently cultivated 'garden' land with perennial crops around the houses. (Small irrigated areas may also be cultivated where water is available). In other words, all the stages of intensification are already present in most villages when land pressure is low, and intensification could be expected to increase as land pressure rises, and fallow land becomes limited. In this study this process will be investigated, together with possible reasons why the systems in many areas do not seem to be changing rapidly enough to maintain or increase productivity under rising population pressure.

1.5. Complexity.

Although the above paints a relatively simple picture, it is important to stress the complexity and variety of tropical farming systems. The humid zone systems are probably the world's most complex in terms of numbers of species involved and their interactions. Also the 45 countries represented in the African savanna have an enormous diversity of environmental, ecological and socioeconomic conditions, which lead to a great variety of farming systems.

The relatively simple view of farming systems as man-managed ecosystems appears useful for the present purposes, but farms are, of course, parts of many other systems, and they interact in many ways with these systems. These hierarchies of systems have been discussed by Ruthenberg (1980), Norman et al. (1981), and Okigbo (1984), among others.

1.6. Bioclimatic Zones

For the purposes of this study, in view of the over-riding importance of climate, and particularly the length of the growing season and the corresponding dry season in determining the types of natural vegetation and the possibilities for rainfed agriculture in tropical Africa, a classification mainly based on bioclimatic zones as defined by Phillips (1979) will be used. This tentative classification also owes much to the work of Chevalier (1900) as further refined by Kowal and Kassam (1978) for West Africa, and to the FAO Agro-Ecological Zones Project (1978) and related studies (Higgins et al 1982).

This study attempts a preliminary review of literature on rainfed smallholder farming systems in each bioclimatic zone represented in the tropical African savanna, by taking each zone in turn and describing selected farming systems in that zone, one by one. The zones are defined as follows (Table 1) and are described in considerably more detail in Chapters 3 - 7.

Table 1. Bioclimatic zones of the African savanna.

This Study Chapter	Bioclimatic Zone	Equivalent Ecological Region West Africa	Equivalent Ecological Region Eastern and Southern Africa	Mean Annual Rainfall mm	Length of growing season days
3	Sub-desert	Northern Sahelian	Sub-desert	0-300	0-60
4	Arid Savanna	Southern Sahelian	Acacia Woodland	300-600	60-90
5	Sub-arid Savanna	Sudanian	Southern Miombo Woodland	600-900	90-140
6	Sub-humid Savanna	Northern Guinean	Northern Miombo Woodland	900-1200	140-190
7	Humid Savanna	Southern Guinean	Derived Savanna	1200-1500	190-230

Fig 5 represents a tentative attempt to map these bioclimatic zones.

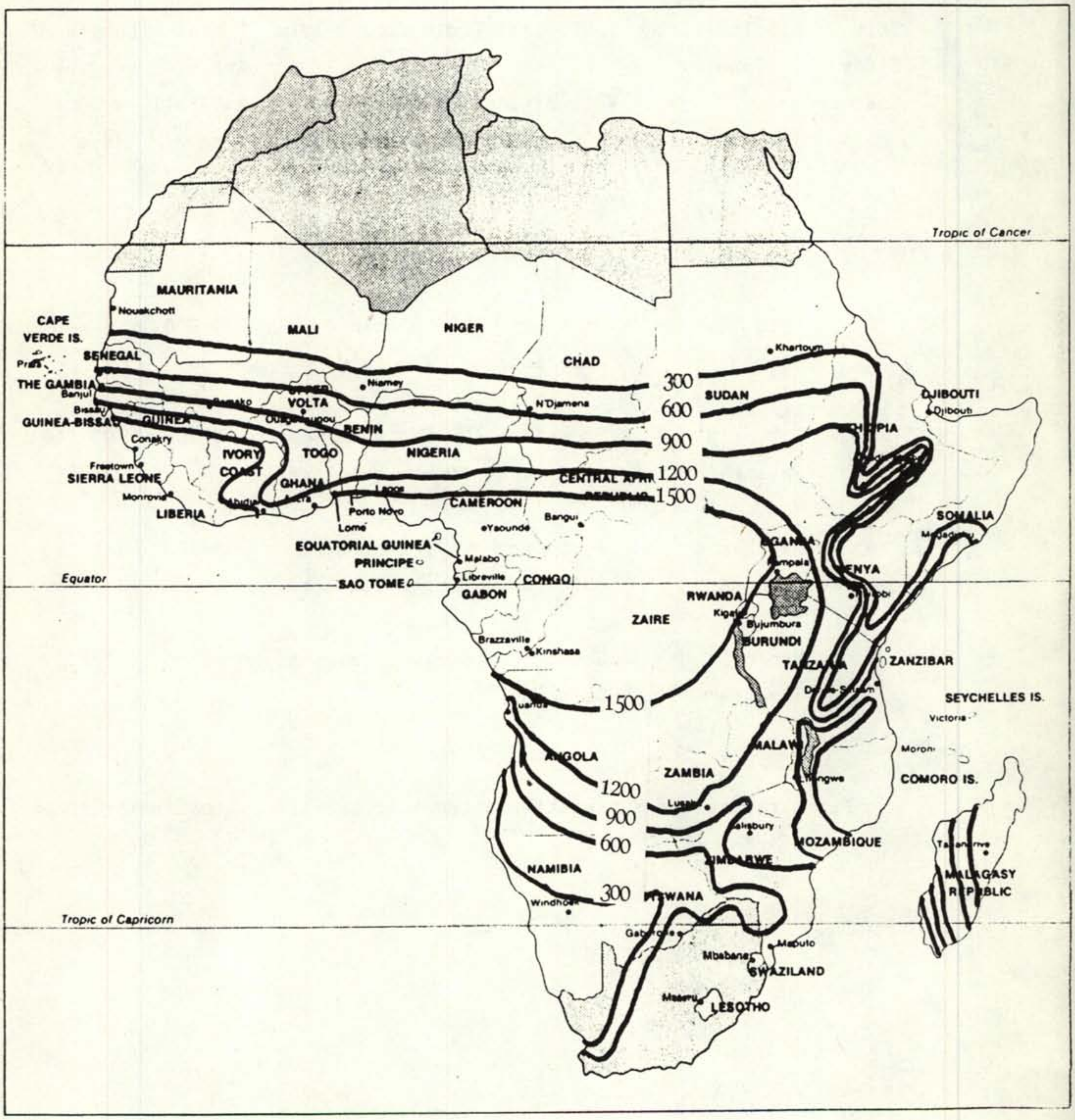


Fig 5. Bioclimatic zones of the African savanna.

In this paper, selected farming systems in each zone are described in turn, starting with the sub-desert zone.

For example, the description of farming systems in the arid savanna zone starts on the West African coast where this zone is represented in Senegal, and follows the zone eastwards, then southwards and finally westwards as it forms a great arc between the desert and savanna environments of Africa. Each zone is then covered in the same way, by selecting and summarizing relevant literature on some of the farming systems, as they have become available to the author. Large-scale irrigation systems are not included in this study, but where small-scale irrigation is a part of the mainly rainfed farming systems described, it is included. Similarly, systems which are mainly pastoral are not considered, but although the study is biased towards the cropping aspects of farming systems, where livestock are part of these systems, some consideration is given to their place in the systems.

It is hopeed to include more complete data on additional systems in later versions of this paper.

1.6.1. Reasons

The main reason for reviewing the systems in each bioclimatic zone in turn is that it is considered that these rainfed systems are mainly determined by the environment, and particularly by the rainfall, and its distribution in terms of the length of the dry season or seasons. Therefore all the systems throughout Africa which are in the same zone have many common features. developed by farmers often independently, in response to similarity in the rainfall patterns. At the same time, there are differences, sometimes due to other environmental factors such as soil type, altitude etc, sometimes to land use intensity due to population pressure, and sometimes to social and economic factors such as farming or land tenure traditions, markets, availability of inputs etc.

1.7. Incentives

The farmer and his family are assumed to respond to incentives, as people do everywhere. It seems doubtful whether there is such a person as a purely subsistence cultivator, as even in the most remote areas some exchange of produce in local markets usually takes place. But the extent to which farmers who are mainly oriented to subsistence, place food crop production in their priorities, needs investigation, as do the levels of incentives in relation to risk and other constraints required to induce farmers to change their priorities and practices.

Chapter 2. THE ENVIRONMENT

Since a considerable amount of information is available elsewhere on the African environment (e.g. see Harrison Church et al. 1965, Kowal and Kassam 1979, Russell 1962, etc.), this chapter will be confined to those aspects which are critical in relation to farming systems. These are climate and soils. Topography is also important, but it is too location-specific to be considered for the whole of the savanna areas, so it will be included in the consideration of each system. Natural vegetation is the result of the interaction of climate and soils, and it will be briefly discussed under each bioclimatic zone, but in this study the main emphasis will be on the existing vegetation which is the result of the effects of man and his domestic animals on the natural vegetation..

2.1. Climate

Climate is the main determining factor for agriculture in Africa, or indeed throughout the world. In temperate regions, low winter temperatures limit active growth to a summer season of a varying length, but in tropical Africa, with the exception of certain highland areas, temperatures are generally high. So the main determinant of crop growth is rainfall, except in the limited areas where irrigation is practiced. Even these irrigated areas are dependent on rainfall to recharge the rivers or ground water reserves from which irrigation water is obtained.

Rainfall in the tropics depends mainly on the movements of the air masses which cover the globe. (Cochemé & Franquin, 1967.) The sun is over the tropic of Cancer at 23½º N on June 21st, the equator on September 21st, and the tropic of Capricorn at 23½º S on December 21st. The sun's heat causes a low temperature zone which encircles the earth roughly parallel to the equator, and which moves north and south following the sun, usually with a lag-time of 4-6 weeks. This zone is called the Inter-Tropical Convergence Zone (I.T.C.Z.).

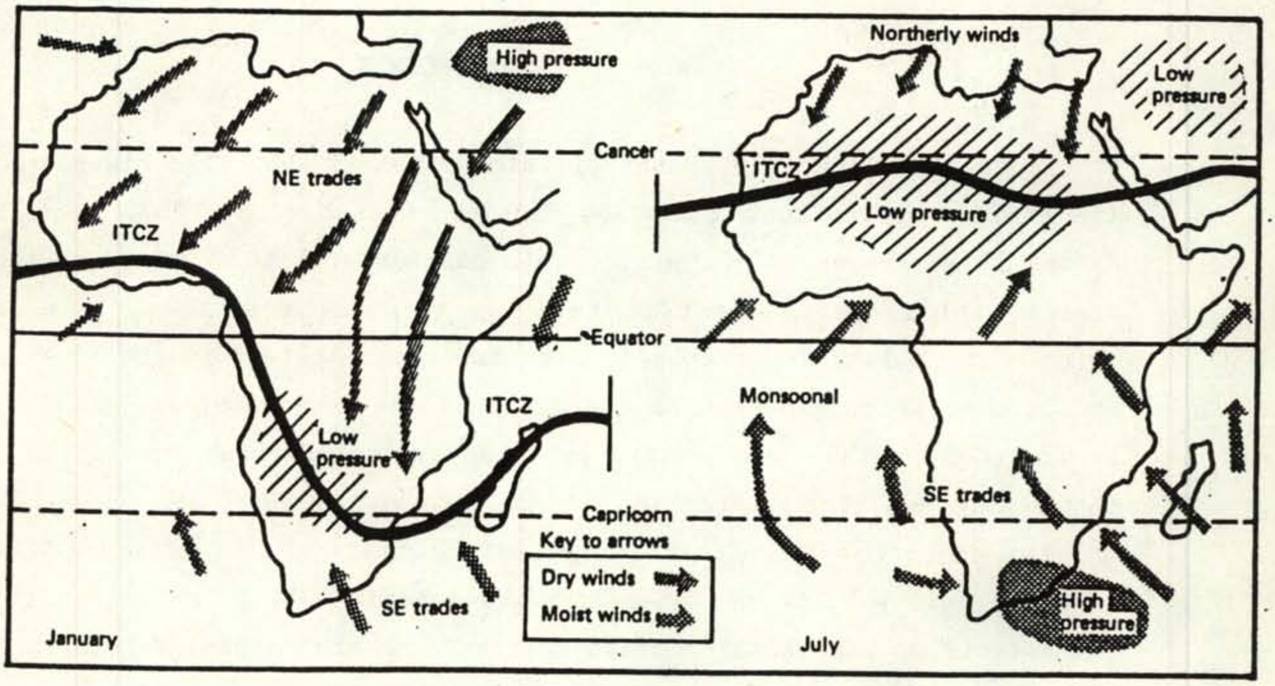


fig. 6: Prevailing winds and location of the ITCZ over Africa. January and July.

Figure 6 shows the approximate locations of the I.T.C.Z. over Africa in January and July. As the air is heated in this zone, it rises forming clouds and rain. North and south of the limits of movement of the I.T.C.Z. are the high pressure anticyclones which also encircle the earth. In Africa the northern high pressure belt causes the Sahara Desert, while the southern one causes the Kalahari Desert.

2.1.1 Rainfall Distribution

Fig 7 indicates the mean annual rainfall distribution of Africa. It is clear that the equatorial region, which is crossed by the ITCZ twice a year, is a zone of high rainfall, particularly in west and central Africa, where westerly winds bring rain from the Atlantic Ocean. For the same reason this zone has relatively well distributed rains throughout the year, though these rains tend to fall in two rainy seasons from about March to June and August to November, separated by two short dry seasons. Further north and south, however. as the ITCZ moves towards its limits, the rains become confined to one rainy season, which becomes shorter in duration and more limited in amount and reliability, the further north or south one goes, until the desert zones with virtually no rains are reached.

2.1.2. Rainfall Variation

One of the most difficult factors with which farmers have to contend, particularly in the semi-arid areas, is rainfall variability. Although farmers always have some traditional rough and ready knowledge of rainfall patterns in their own areas, they may often be taken by surprise, particularly if a run of wet years is followed by several dry years as happened throughout semi-arid Africa in the early 1970's and 1980's. There has been much discussion of possible long-term downward trends in mean rainfall in semi-arid Africa, but Pereira (1981. p6) points out that:

> "Two of the world's major meteorological computer centres at Bracknell in Britain and at Boulder City in USA have made very thorough studies of the world data. They have detected no evidence of overall significant trends during the past 200 years, either in the means of climatic values or in variability about these means."

However, there appears to be a need for more rigorous analysis of long runs of rainfall data to try to determine trends and cyclical or other patterns. One way of approaching this problem is to calculate rainfall probabilities for recording stations where adequate data is available. The World Meteorological Organisation is active in developing methods for the standardised recording and communication of weather data.

2.1.3. Rainfall Intensity

Kowal and Kassam (1979) give a useful summary of information on rainfall intensities in the West African savanna. They point out that

> "The intensity of rainfall and energy load of individual rainstorm systems in the west African savanna is much greater than that of temperate and sub-tropical rainstorms and presents special problems in agricultural management and land conservation."

Working at Samaru, Nigeria, they found that peak rainfall intensities of 120 - 160 mm/hour were not uncommon. They showed that there were positive correlations between the rainfall intensity and the drop number and size, and between the peak intensity and the amount of rainfall in the storm (R = 0.78). Following from this they found a highly significant correlation (R = 0.99) between the amount of rainfall, the rainfall intensity, and the kinetic energy load of the raindrops in a particular storm. Analyzing the data from several seasons, they found that storms with less than 20 mm rainfall did not produce any runoff on cultivated areas of gentle slope, whereas all storms of over 20 mm rain produced some run off, the amount depending on the rainfall duration and intensity. On this basis, 32 storms containing about 58% (635 mm), of the seasonal rainfall fell in storms of over 20 mm and were erosive, and 53 storms containing about 42% fell in storms of less than 20 mm, and were non-erosive. An analysis of the seasonal distribution of the storms indicated that erosive storms were about as likely to occur at any time during the season, but since the number of storms was correlated with the amount of rainfall, a greater number of erosive storms fell during the three wettest months of July, August and September than during the remainder of the rainy season.

Roose, working at Adiopodoume´ near Abidjan, on a ferrallitic soil (oxisol) with a 7 % slope, found that the few exceptionally heavy storms with over about 100 mm rainfall caused a high percentage of the annual soil loss (Table 2).

Date	Land use	Rainstorm amount mm	Soil loss t/ba	% of annual soil loss
10/6/67	groundnuts-flat	110	50.1	42
28/5/78	bare soil	140	47.1	28
28/6/71	bare soil	230	34.4	25

Table 2. Soil loss in exceptional storms at Adiopodoume´, Ivory Coast (Roose 1977).

Charreau and Nicou (1971) found that a quarter of the rainfall at Bambey, Senegal fell at intensities of over 50mm per hour, and they recorded intensities up to 740 mm per hour over short periods in occasional heavy storms. Charreau (1974) has pointed out that on average tropical rains have six to ten times more erosive power than temperate rains. Although detailed information is still lacking on both the erosivity of the rains and the erodibility of the soils in many parts of Africa, it is clear that the risks of accelerated erosion are very high in these areas. On the other hand, Thomas et al. (1981) working at an altitude of 1500-2000m at Isuni in Machakos District, Kenya, only recorded 5 storms with intensities greater than 25mm per hour for a 15 minute duration out of 30 storms recorded during November and December 1978. They concluded that Isuni was located in an area of low erosivity.

2.2. Other Climatic Factors.

2.2.1. Solar Radiation, Light, and Temperature

Incoming solar radiation at the top of the atmosphere is relatively constant in the tropics, but global radiation reaching the earth's surface is greatly affected by cloud, particularly in the more humid regions. It varies from over 2400kJ cm-2 day-1 in the desert to below 1500 kJ cm-2 day-1 at the southern edge of the West African savanna. The annual range in day-length varies from nil at the equator to nearly 2 hours at 17º N or S (Okigbo 1986, p97).

2.3. Soils

Many of the detailed maps of African soils were produced by French soil scientists working for ORSTOM and IRAT in the francophone countries, Belgian soil scientists with INEAC in Zaire, Rwanda, and Burundi, and British soil scientists in the anglophone countries. Their results are reported in a variety of publications, and some countries have atlases or other publications which contain soil maps. These are too numerous to be detailed here, but useful reviews of the soils of West Africa are contained in Ahn (1970), and Jones and Wild (1975). East African soils are reviewed in Russell (1962), etc. These publications list references to the papers consulted.

A number of different systems have been used for classifying African soils, which make comparisons between countries difficult. The FAO soil map of Africa ('DHoore, 1964), and the African section of the later FAO/Unesco (1974) soil map of the world represent attempts to draw together the available information on African soils.

Although considerable research and detailed mapping have been carried out on the soils of a number of countries, there appears to be a need for a much greater and more sustained research effort to classify and determine the characteristics of African soils, and particularly to work out improved methods of soil management and conservation.

Since the American system of soil classification (Soil Taxonomy, U.S.D.A. 1975) appears to be gaining increasing acceptance worldwide, the map (Fig 8), represents a first approximation of the application of this system to African soils (Aubert and Tavernier 1972). Although considerably more detailed work needs to be done on the adaptation of the Soil Taxonomy classification system to African soils, there appear to be substantial advantages in the use of this system to allow comparisons between African soils and other similar soils worldwide. Although a map on this large a scale obviously has a limited value for any detailed discussion of agricultural uses, certain broad generalisations may be attempted, following Ahn (1970 p220).

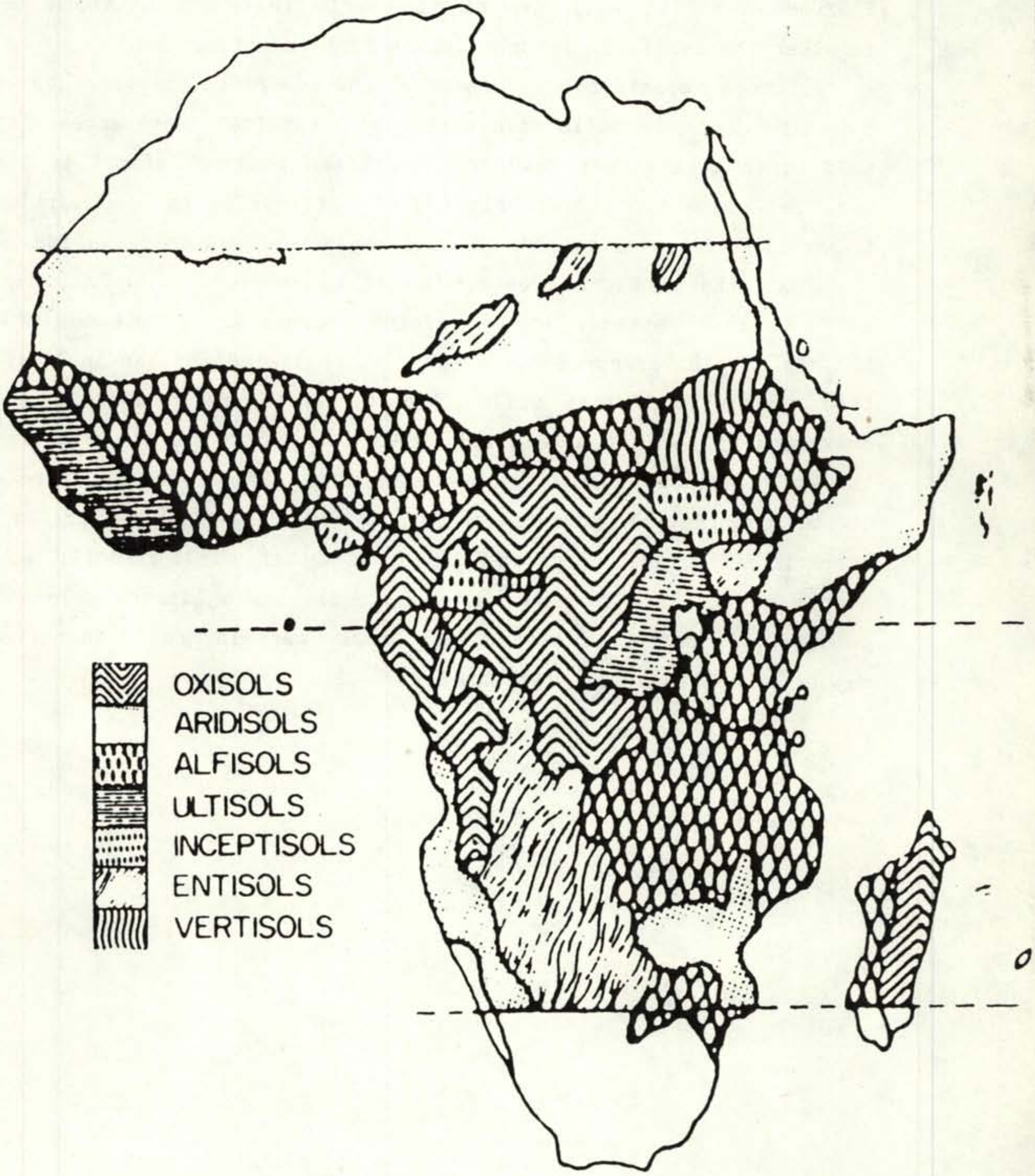


Fig 8. The soils of tropical Africa. (Aubert and Tavernier 1972).

Alfisols

The map indicates that the soils over vast areas of semi-arid Africa are classified as alfisols. The alfisols are a varied group . They are distinguished by an accumulation of clay in the subsoil, and normally contain some bases.

Oxisols

Oxisols are widespread in the high rainfall areas of the Congo basin and extend through Zambia, Mozambique and neighbouring countries into Madagascar. They are the most highly weathered tropical soils and are characterised by an oxic horizon in the subsoil. They have a low cation exchange capacity and little clay content.

Ultisols

These are another group of soils which are mainly found in relatively humid areas such as Uganda, parts of Eastern Zaire, Guinea, and Liberia. Like the alfisols they are defined as having a clay layer in the subsoil, but they are relatively highly weathered soils with few bases in the profile, but not as weathered as the oxisols.

Entisols These are pedologically young soils in which the horizons are only slightly developed, or undeveloped. They include many recently deposited alluvial materials and some young soils on inert and resistant parent materials. They are widespread in the drier areas of south-west Africa.

Inceptisols

The inceptisols are more developed than the entisols but are also relatively young. They are not strongly weathered, and include some poorly drained gley soils without well-developed horizons, and shallow immature soils of steep slopes. Their largest area of occurrence is in Central Zaire.

Vertisols

These are a relatively unique group of soils, often described as black cotton soils. They are black or dark coloured clay soils which form deep cracks when they dry out. Because of the high clay content they are difficult to cultivate when dry, and become very sticky when wet. Their largest area of occurrence in Africa is in the central Sudan and the Ethiopian highlands, but they are also found in limited areas around Lake Chad and in eastern Africa.

Aridisols

As the name indicates, these are soils of arid regions such as the Sahara and Kalahari Deserts. They are often wind-blown sands, but some rocky or stony soils are included.

2.3.1. Savanna Soil Characteristics

Kowal and Kassam (1978) have reviewed much of the literature on the soil characteristics of the West African savanna. The following description draws heavily on their synthesis.

They emphasise the critical importance of soil depth, due to the presence of ironstone gravel or plinthite, which can restrict root growth at varying depths, and interfere with cultivation. They also stress the sandy nature of most savanna soils, though some of the leached alfisols and ultisols contain increasing amounts of mainly kaolinitic clay in the deeper horizons. They stress the importance of soil structure and surface characteristics, particularly when the vegetative cover is removed, and the soil surface is exposed to heavy rain, when capping (crusting) often takes place.

Many savanna soils are fine sandy loams, with high bulk densities, which can restrict root growth. On these soils ploughing or deep digging gave crop yield increases between 20-70% higher than those obtained after shallow hoeing, with an average increase of 24% (Charreau 1974)

Moisture storage in the top metre of soil varies from about 80 mm in sandy soils to about 150 mm in soils with a higher clay content (Kowal & Kassam 1978, p 127). The cation exchange capacity (CEC) of most savanna soils is low, usually in the range 3 - 8 me/100g at pH 7.0, and is closely related to the organic matter and clay contents of the soil. Soil reaction (pH) normally varies between about 5.0 - 7.0 on different savanna soils. Below about pH 5.3 soil acidity may limit the growth of some crops. For example maize and groundnuts are likely to be affected. Under continuous cropping, and particularly if large quantities of ammonium sulphate or urea are applied, the soils tend to become more acid, reducing the availability of phosphate.

Organic matter (OM) is of critical importance in savanna soils. Under a good cover of bush, or even grass fallow, organic matter increases, the soil surface is protected, soil organisms such as earthworms are active, and within the limits of the soil's inherent fertility, productivity is high. Once the vegetation is burned, or the soil is cultivated, a rapid breakdown of organic matter takes place, and this is proportional to the temperature.(Birch & Friend 1956). Kowal & Kassam (1978 p 103) point out that the effects of organic matter on soil fertility in tropical soils continue to arouse considerable controversy. However, it appears clear that on the less fertile sandy soils, the addition of organic matter can increase yields even if sufficient nutrients are supplied in the form of fertilisers. This subject is of such importance to the future of agriculture in the tropics, that it appears to need considerably more research attention.

Macronutrients

Phosphorus

Phosphorus deficiencies are widespread in savanna soils, and many authorities consider lack of phosphorus to be the primary limiting factor in savanna crop production (Kowal & Kassam 1978, p143). Average phosphorus contents in surface soils range from about 80 - 150 ppm, compared with temperate soils which have average contents ranging from about 1500 - 3000 ppm. Part of the soil phosphorus is in the form of organic P, but this tends to be low in most savanna soils (15 - 60 ppm - Goldsworthy & Heathcote 1963). Losses of phosphorus from soils by leaching are generally low, but much of the soil phosphorus is held in various ways making it only slowly available to crops. However phosphorus fixation is not usually a serious problem in most savanna soils, except some of the heavier East African soils.

Many African countries have naturally occurring deposits of phosphate rock (PR), and some of these deposits are being developed for both local use and export. For example Togo and Senegal export considerable quantities of phosphate, and Senegal uses some of its production locally. These phosphate rock deposits vary greatly in their % P and in the form and availability of the phosphorus. The location of some of the deposits is remote, and this determines the ease of extraction and transportation. For example Mali has started developing a deposit at Tilemsi in the Sahara desert north of Gao, and trials have shown that PR from this deposit can be applied directly to crops after grinding, with promising results. The deposits in Togo, Burkina Faso, and Niger, on the other hand, appear to require processing to increase solubility before use. Since unlike nitrogen and other nutrients, phosphorus does not move much in the soil, it is important to ensure that phosphorus fertilizers are placed close to crop roots, particularly since phosphorus is especially important for early root growth.This can be done by using a placement drill

Nitrogen

The nitrogen status of soil is closely associated with the soil organic matter, and therefore varies with the OM content. Also Birch (1958) showed that the first rains produce a flush of mineral nitrogen in a previously dry soil containing organic matter. This important phenomenon is often called the "Birch Effect". The amount of N mineralized varies, but it can be as much as 70Kg N ha-1 after manuring (Wild 1972). Unlike phosphorus, nitrogen can be rapidly lost from the soil by leaching, or by volatilization from the soil surface. These losses can be reduced by early planting of crops, so that the crops can take up some of the mineralized nitrogen before it is lost by leaching. Another way of reducing the losses is by careful timing of fertilizer nitrogen applications, usually about 2 - 6 weeks after planting (Charreau 1974).

An important source of nitrogen is from biological nitrogen fixation (BNF) from the atmosphere. Rhizobium bacteria symbiotic in the roots of leguminous plants are the main source, but other sources include free-living nitrogen fixing bacteria and bluegreen algae.

Traditional cropping systems where cereals such as sorghum or millet are intercropped with leguminous crops such as cowpeas or groundnuts appear to assist in reducing nitrogen deficiencies in one or both crops.

Potassium

Although potassium deficiencies have been reported on certain soil types under heavy cropping, in general they do not appear to be limiting to crop production in most savanna regions (Nye & Greenland 1960 p 99). Like phosphate, potassium is returned to the soil in crop residues or other forms of organic matter, and in the ash after burning, and leaching losses are not generally severe, so it is easily recycled. Also although savanna soils are often low in potassium, the nutrient appears to be readily available in most soils. However, under continuous heavy cropping with the removal of crop residues, potassium could be expected to become limiting to the yields of a number of crops, so a careful watch needs to be kept for deficiency symptoms. But this does not imply that the uneconomic use of compound fertilizers containing N,P, and K is justified unless there is strong evidence of the likelihood of potassium deficiencies.

Calcium and Magnesium

The low cation exchange capacity (CEC) of most savanna soils limits the amount of exchangeable calcium and magnesium to about 0.3 - 3.0 me/100g (see p........). In crops growing on arid soils it is often difficult to separate the detrimental effects of lack of calcium or magnesium as nutrients, and the indirect effect of acidity or aluminium toxicity (Kowal & Kassam 1978, p148). Under traditional shifting cultivation on soils with pH above about 5, there is little evidence of much crop response to liming (Nye and Greenland 1960, p97). On more acid soils, and on savanna soils under more intensive cropping with heavy use of nitrogenous fertilizers, the pH may often fall below 5.0, and liming may be necessary, although surprisingly few experiments appear to have been conducted on this important topic.

Small applications of 1-2t ha-1 of lime once in 10 - 20 years often appear sufficient to prevent aluminium toxity, and to correct soil acidities below pH 5.0, and they may give quite large yield responses, particularly in legumes such as groundnuts. For example it has been estimated that about 20% of the cultivated land in Senegal needs liming to correct acidity and prevent aluminium toxicity (Pieri 1974).

Sulphur

Sulphur is mainly contained in organic matter. and like nitrogen it is lost into the atmosphere on burning crop residues or bush or grass fallow. Since savanna soil organic matter levels are generally low, sulphur deficiencies are widespread, particularly in areas remote from the sea or from smoky industries (Nye & Greenland 1960, p 97). Where fertilizers such as ammonium sulphate or single superphosphate are used, little sulphur deficiency occurs, but the increasing use of low sulphur fertilizer such as urea and triple superphosphate can result in sulphur deficiency. Small dressings of up to 20 Kg ha-1 S are sufficient to correct this (Kowal & Kassam 1979, p 148).

Micronutrients

Occasional deficiencies of micronutrients such as boron, molybdenum and zinc have been identified, particularly on plantation crops, and on cotton and groundnuts under heavy cropping. Boron is sometimes routinely added to cotton fertilizers, but care must be taken to avoid toxicity , as the margin between deficiency and toxicity is narrow.

2.3.2. Soil Erosion

It is generally recognized that probably the greatest threat to sustained rainfed agricultural production, and indeed to the continuing prosperity of many of the developing countries in Africa and elsewhere, is uncontrolled soil erosion. Brown and Wolf (1985) have recently suggested that about one billion tonnes of top soil are being lost by erosion each year in Ethiopia. Although the basis for such estimates is not clear, there is no doubt that uncontrolled erosion is causing enormous damage to Ethiopian soils.

As population and land pressure increase, uncontrolled erosion is depleting valuable topsoil, undermining roads and other structures, and causing floods and silting of reservoirs throughout Africa. And yet surprisingly little scientific data on erosion is available from large areas of Africa. Kowal & Kassam (1978) have attempted to summarise the situation in the West African savanna. They point out that in the higher rainfall areas of the Guinea and Sudan savannas, water erosion is most important, whereas in the Sahel, while water erosion can be severe in the southern sub-region during the occasional storm, wind erosion also occurs, and is particularly severe in the north.

Erosion caused by Rain.

Under natural vegetation undisturbed by man or his domestic animals the soil surface is normally protected by leaf litter and a canopy of leaves, and negligible erosion takes place. For example, Roose (1967) estimated the annual rate of soil loss under natural vegetation at Sefa, Senegal (1150 mm rainfall), as between 0.1 - 0.2 t/ha.

At Samaru, Nigeria, with a similar rainfall, Kowal found that runoff and soil loss were negligible even when annual burning was practised. Since soil formation does occur, albeit very slowly, under savanna conditions, it is evident that the rate of erosion under natural vegetation is unlikely to be as great as the rate of soil formation, so a net gain in top soil occurs.

Although rigorous scientific data is scarce, erosion damage under traditional shifting cultivation practices with low population pressures of men and livestock is generally considered to be relatively limited.

Shifting cultivators usually open small plots for 2 - 3 years, leaving the stumps of bushes and trees to regenerate during the fallow period, and maintaining a cover of vegetation or crops on the land during most of the rainy season. Even if some runoff and erosion does occur within the plot, it is usually arrested as soon as it reaches natural vegetation at the edge of the plot (Nye & Greenland 1960, p88).

The danger comes as population pressure causes an increasing proportion of the land area to be cultivated for extended periods, so that soil fertility and the vegetative cover are reduced, and accelerated erosion takes place if careful precautions are not taken.

Accelerated erosion

The most widely used method of calculating the water erosion hazard is by the use of the Universal Soil Loss Equation, which was developed by Wischmeier in the USA. It can be summarised as shown in Table 3.

EROSION is a function of:-

EROSIVITY and ERODIBILITY

RAINFALL | PHYSICAL CHARACTERISTICS | MANAGEMENT

ENERGY | LAND MANAGEMENT | CROP MANAGEMENT

$$A = R \times K \times LS \times P \times C$$

where A = soil loss (t ha-1)

R = rainfall erosivity index

K = soil erodibility factor

L = length of slope

S = slope factor

C = crop management factor (Characteristics of vegetative cover protecting the soil against erosion)

P = conservation practice factor (The effectiveness of land forms such as ridges, terraces, etc.)

Table 3. The Universal Soil Loss Equation (Wischmeier and Smith 1978, adapted from Hudson 1981, p47)

Vegetative Cover (C)

It has already been pointed out that a thick forest cover almost completely protects the soil from erosion, and erosion losses under natural savanna vegetation are usually small, though some runoff may occur. Although data from erosion studies in much of Africa are scarce, Roose (1977) has reported on many years of work in francophone West Africa. For example on a ferrallitic soil at Adiopodoume', near Abidjan, Ivory Coast, with an annual rainfall of 2138 mm, he recorded the following results (Table 4.).

		Soil loss t ha-1 yr-1	
Crops	Slope %	Range	Mean
Cassava and yams	7	22-93	32
Maize	7	35-131	92
Groundnuts	7	59-120	82
Bare soil	7	69-150	138
" "	4.5	34-74	60
" "	20-23.3	266-622	570

Table 4. Annual soil loss by water erosion at Adiopodoume' (Roose 1977 p.51 table 14).

These results suggest that the least erosion (averaging 32t ha^{-1}year^{-1}), occurred under cassava and yams, while maize and groundnuts permitted about 80 - 90 t ha-1 erosion, and bare soil on the same slope allowed a more severe loss of 138t ha-1. One of the characteristics of erosion is its extreme variability, depending on the particular conditions prevailing. The above data, together with other results quoted by Charreau (1974), indicated that the annual soil losses from cultivated fields under a wide range of conditions varied from about 0.1 - 138 t ha-1. Thus the higher figure is over 1300 times the lower figure.

In general the extent of erosion is inversely proportional to the vegetative cover over the soil during the rainy season, whether in the form of natural vegetation, perennial crops, one or more annual crops, or leaf litter or mulch on the soil surface. It follows from this that perhaps the most important farming practices for the prevention of erosion are those which maintain an effective vegetative cover over the soil for the maximum time during the rainy seasons. This will be considered in more detail in the next chapter, but at this stage the importance of early planting of annual crops cannot be overstressed.

Soil type and structure.

The erodibility (K) of savanna soils, or their vulnerability to erosion, is generally high, since many of the soils are sandy, low in organic matter, and of unstable crumb structure (Kowal & Kassam, 1978, p168).

It appears that certain types of fine sandy loam, or sandy clay loam soils which are low in organic matter through over cultivation, and therefore have unstable structures, are particularly liable to erosion because of their tendency to cap. When a high intensity rainstorm hits bare soil, the fine soil particles are loosened by rainsplash, and are washed down into the pore spaces which quickly become blocked. Once the pore spaces are blocked or capped, and the soil surface is saturated, runoff starts. The fine organic matter and lighter soil particles are the first to be removed by runoff, and measurements show that the eroded material contains 2 - 4 times more of the fine particles containing nutrients than the original soil (Jones & Wild 1975, p 65. Kowal & Kassam 1978, p.171) On these soils, when the surface soil dries, the cap can become so hard that germinating seedlings of some crops cannot penetrate it. Also further heavy storms can cause severe erosion because the cap causes most of the rain to run off instead of infiltrating into the soil (Ker et al. 1978, p 39).

On the other hand, the coarse dune sands which are found in parts of the Sahelian and Sahara zones appear to have such high infiltration rates that little water erosion takes place. Instead, these soils are liable to erosion by wind, and this is discussed later. The soils of volcanic origin which occur in parts of East Africa often have such a stable crumb structure that their erodibility appears to be low, except under the severest storms.

Angle(S) and length(L) of slope.

The amount and speed of runoff depends on the steepness of the slope. The scouring capacity of running water increases as about the fifth power of its velocity. (Jones & Wild 1975, p62). Therefore slow-moving runoff may cause little erosion, although it can, of course, reduce the amount of soil moisture available for plant growth. As the runoff picks up speed, it causes sub-rill erosion, which is the most widespread of erosion damage, but is often difficult for the untrained observer to spot. This type of erosion gradually removes the most fertile topsoil, until only infertile subsoil remains. It is particularly serious where a shallow topsoil overlies an iron-pan or concretionary layer. In many parts of Africa all the topsoil has been removed by erosion, leaving massive plinthite which is useless for agriculture, or ironstone gravel which is almost as bad.

As runoff accelerates down the slope, it becomes concentrated into small rivulets which cause rill erosion. This is easier to observe than sub-rill erosion, and on long slopes with inadequate protection the water may eventually form gullies which can cause severe damage.

Wind erosion

Like water erosion, soil erosion by wind is only serious where there is no protective cover of vegetation. Wind erosion is particularly severe in the Sahara and Kalahari Deserts and in the sub-desert fringes (e.g. The northern Sahelian Zone in West Africa).

Although experimental evidence is lacking, there appears little doubt that an increase in wind erosion has occurred in these desert and sub-desert areas mainly as a result of the destruction of much of the natural vegetation. This destruction is mainly due to overgrazing by excessive numbers of domestic livestock. Damage to the tree cover has also been caused by the clearing of bush for increased cultivation and for firewood. Wind erosion seems to be mainly confined to the regions receiving less than about 500mm mean annual rainfall, as in the higher rainfall areas there is usually enough vegetation - sometimes in the form of crops - to protect the soil from serious wind damage.

During the dry season in West Africa, the north-east trade wind - the Harmattan - often carries a cloud of dust which covers much of West Africa, even as far south as the Nigerian and Cameroon coast.There have been reports that West African dust has been identified as far from Africa as the West Indies and parts of Europe. Although this consequence of wind erosion may have occurred from ancient times, some observers consider that the quantities of dust carried in recent years may have increased, particularly during drought periods, but few quantitative measurements seem to be available.
Hudson (1981) has reviewed the subject of wind erosion in some detail.

Desertification

The Sahelian drought of 1968-73 aroused world-wide concern about the possible spread of the Sahara desert into the Sahel region, and perhaps further southward into the Sudanian region. The United Nations conference on desertification, held in Nairobi in............(refs) both attempted to summarize some of the available information on the subject, and had the effect of arousing further interest. Many widely varying estimates of the rate of spread of the Sahara have been published, but these do not seem to be derived from rigorous scientific studies. The arid area certainly fluctuates according to the rainfall, and particularly during a run of dry years such as occurred from 1968-73, and again from 1979-84, the arid area with its accompanying wind erosion extended southwards. But it is not clear what happens during a run of wetter years. Certainly there is some recovery of the vegetation in these drought-affected areas, and since the livestock population may have been reduced during the dry period by migration southwards, or by deaths , the vegetation has a chance to re-establish itself. But when the livestock migrate northwards again and regain their former numbers by breeding, the grazing pressure on the vegetation may again become heavy and the next dry period may lead to further damage, which may eventually become irreversible.

2.3.3.Soil Conservation.

Since soil conservation must be an integral part of farming systems, it is considered in the section on farming systems.

2.4. Land Use and Farming Systems.

A major contribution to the understanding of African small-holder land use and farming systems was made by Allan, Trapnell and their colleagues working in the country that is now Zambia. The basic concept was that;

> "in an underdeveloped country the study of vegetation in relation to soils, climate, and other environmental factors, and the classification of plant associations in accordance with these factors, should provide the most practical single guide to agricultural and forestry potentials" (Allan 1965, p 13).

Allan points out that down through the ages and throughout the world, the subsistence cultivator has needed a detailed knowledge and understanding in order to survive;

> "He can rate the fertility of a piece of land and its suitability for one or other of his crops by the vegetation which covers it, and by the physical characteristics of the soil, and he can assess the 'staying power' of a soil, the number of seasons for which it can be cropped with satisfactory results, and the number of seasons for which it must be rested before such results can be obtained again. His indicator of initial fertility is the climax vegetation, and his index of returning fertility is the succession of vegetational phases that follows cultivation. In many cases his knowledge is precise and remarkably complete. He has a vocabulary of hundreds of names of trees, grasses and other plants, and he identifies particular vegetation associations by specific terms. This fund of ecological knowledge is the basis of 'shifting cultivation'" (Allan 1965, p5).

Perhaps the major contribution of Trapnell, Allan and their colleagues was in conceptualizing and reducing to quantitative terms some of the complexities of the so-called 'shifting cultivation'. These concepts can be summarized as follows:-

1) Cultivable and Uncultivable Land.

This is simply an assessment of the proportion of potentially cultivable land in any particular area or country. Obviously the proportion of cultivable land will vary considerably, depending on many economic, technical, demographic, and social factors. For example, in dry areas part of the land may not be cultivable without irrigation, and the irrigation potential will depend on the availability of water, and on technical, economic and social factors in practicing irrigation. But even in the most favourable circumstances, it is found that a considerable proportion of the total area is usually uncultivable under the traditional systems of land use. In Zambia this was estimated to be as high as around 90% of the total land area.

2) The Land-use Factor.

This is a measure of the intensity of cultivation of a particular land type under traditional farming practices. Allan (1965) defines this as "the relationship between the duration of cultivation and the period of subsequent rest required for the restoration of fertility". For example , if a cultivator has 1 ha under crops for 2 years, and the land only requires 2 years of rest to regain its fertility, he only requires double the amount of land under cultivation to maintain his farming system and crop yields, so the land-use factor is 2.

3) The Cultivation Factor

This is the area cultivated per head of population. In four distinct and widely separated systems in Zambia, three growing maize or sorghum and one growing cassava as staple foods, the cultivated area varied very little, from 0.41 to 0.45 ha or just over 1 acre per person. (Allan 1965, p57). On soils of lower fertility a larger area of 0.68 - 0.73 ha (1.67 - 1.80 acre) per person had to be cultivated to obtain sufficient food.

In the parts of Kenya and Uganda with two rainy seasons per year, the areas for subsistence cultivation of annual grain crops, or bananas and other crops were somewhat lower, at 0.17 - 0.27 ha or about ½ acre per person. But in Teso District, Uganda, where ox-ploughs were used, and with an uncertain second rains, the area was about 0.37 ha, or nearly 1 acre of food crops per person.

In West Africa the average food crop area per person in the rainforest areas of Ghana, Liberia, and Congo appears to be about 0.18 ha, or just under ½ acre per person, whereas in over-populated areas of Northern Ghana where ox-ploughs are used the areas vary from 0.27 - 0.72 ha (0.60 - 1.79 acres).

Allan (1965, p65) makes the important point that;

> "Increasing population pressure commonly causes an increase in the cultivated area per person, as a reaction to declining yields, and it is only in the later stages, when practically all the resting and marginal land has been absorbed, that subdivision and fragmentation become apparent."

4. Critical Population Density.

This concept was developed as a result of an investigation into a food shortage in an area of Northwest Zambia. This shortage had occurred as a result of a poor season for sorghum, the local staple crop, because of excessive rain, and a labour shortage. The farming system practised by the Lamba people who live in that area was a variant of the *citemene* system which was widely practised in the miombo woodland areas of Northern Zambia and the neighbouring countries. This system represented a unique adaptation of the shifting cultivation system to the soils of extremely low fertility which appear to be widespread throughout that region. Although it is difficult to categorise the majority of these soils according to the U.S.D.A. classification without considerably more data, many of them would appear to fall in the oxisol group (Fig 8, p21).

The typical feature of these systems was the felling or lopping each year of a large area of woodland, an area several times greater than that on which crops were grown. The branches were then stacked in an area that might only represent 10 % or less of the area originally cleared, and burned when dry. Finger millet (Eleusine coracana)or sometimes sorghum was then sown in the ashes. Typically, only one crop was grown, after which the land was abandoned for a long period of 20 years or more for regeneration of the woodland. There were, however, many variants on this system, depending on the soil fertility, which are well described by Allan (1965, p 66 onwards). About the food shortage, he continued(p 84),

> " Much more alarming than the immediate problem- which was, of course, solved by the issue of famine relief and seed- was the outlook for the future. Conditions throughout most of the area were such as to justify a prediction of recurring food shortages and the ultimate collapse of the system of food-production, possibly within a decade. It was evident that the area was greatly over-populated in relation to the system of land-use and that a continuation of this situation could result only in progressive deterioration of the soil and accelerated erosion.

There was at that time no knowledge or experience of the possibilities for permanent cultivation on these unpromising soils. The working out and adequate trial of improved systems, capable of supporting relatively high population densities and within the means of the Lamba, would have required many years even if the resources for doing so had been available.......Furthermore, the Lamba had very few livestock, far too few to provide manure sufficient for the maintenance of soil fertility, and the great majority had none at all-not even a sheep or a goat.....In the meantime, it might reasonably be predicted, the land,.... and with it the people, would be reduced to the final stages of degradation, and the ultimate problem would be one not only of introducing a new system but of rehabilitating the devastated land" (Allan 1965, p 84).

As a contribution to the solution of this problem, a first attempt was made to estimate the land requirements of shifting cultivation in this part of Zambia. A detailed survey measured the area of land under each of the vegetation-soil categories which had been previously defined, and showed that a large proportion consisted of soils with a low carrying capacity, or was uncultivable. The cultivable percentage was estimated to be 22.

The land-use factor was then calculated for each of the vegetation-soil types, and this varied between 3 and 13 depending on the soil fertility. On this basis the carrying capacity of the land varied between about 2 ha per person on the most fertile soils to about 100 ha per person on the least fertile soils. The cultivated area per head of population (The cultivation factor) was calculated as 0.4 ha. Combining the above factors, the critical population density for this area of 627 square kilometres was calculated as about 7 people per square kilometre.(the critical population density was defined as the maximum population density the existing farming system was capable of supporting in that environment *without damage to the land*. (Allan, 1965, p 89).

When an estimate of the actual population was made it was found that there were about 17 to the square kilometre, over double the critical density. Although the detailed estimates may be disputed, there appears to be little question that Allan and his colleagues developed a workable method of analysing land use under shifting cultivation and similar farming systems. As part of their method, they classified the main vegetation-soil types into five major land-use categories ; Permanent or Semi-permanent land, Re-cultivation land, Shifting Cultivation land, Partial Cultivation land, and Useless or Waste land. In order to make this system more widely applicable outside Zambia, they later introduced an additional category of Recurrent Cultivation land.

Allan's concept of critical population density can assist in the understanding of many of the problems and tensions which are occurring in African farming systems at the present time. In the case of the Lamba, outlined above, fortunately there was an area of relatively fertile unpopulated land not far from the overpopulated area described, so some of the Lamba were able to shift to the unpopulated area, so relieving the pressure on their original home area.

In many parts of the savanna the population pressure on the land is already exceeding the available resources *under existing farming systems,* so exceeding the critical population density. Unless underpopulated fertile land is available for the surplus population to move into, or rapid improvements take ~~place~~ place in the farming systems, considerable hardship will occur.

Higgins et al. (1980), working in the FAO Agro-ecological Zones and Potential Population Supporting Capacity Projects have collected a mass of information indicating which areas worldwide are most likely to be under stress at the present time. They have shown that although the overall population density is generally low in the areas with low rainfall and short growing seasons, the critical population density in those areas is often even lower, so the land is already over-populated. This clearly agrees with Allan's conclusion (outlined above), that the population density of the Lamba people in the area described, of 17 per square kilometre, greatly exceeded the critical density in that area, which was calculated as 7 per square kilometre.

Areas mainly occupied by pastoral people like the Touareg of West Africa or the Turkana of Kenya have a particularly low critical population density because of the heavy dependence of these people on large numbers of livestock per head of population for survival. For example, Dyson-Hudson (1980, p 180) has shown that pastoralists in Kenya require up to about nine large stock and fourteen small stock per person to survive under their traditional system. With increasing numbers of people, these pastoralists can quickly find themselves trying to keep far greater numbers of stock than the rangeland can carry, so severe overgrazing and often, deaths of stock in dry periods, serious damage to the environment, and sometimes, human deaths may result.

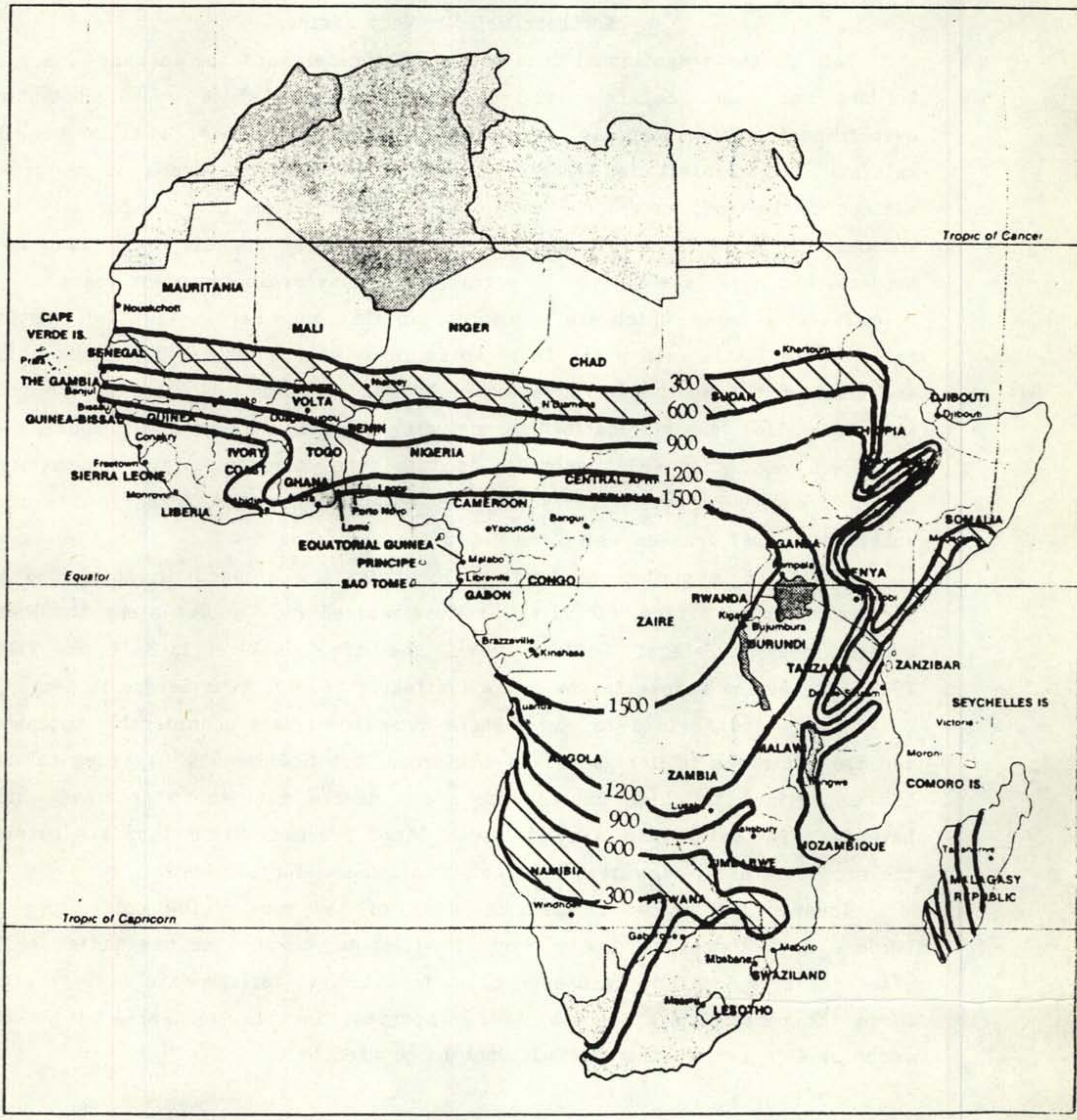
2.5. Bioclimatic Zones

The patterns of cultivation vary enormously throughout the African savanna, depending on soil fertility, climate, and the needs and preferences of the cultivators, particularly in relation to the crops which they prefer to grow and which are adapted to the environment, but not surprisingly, it appears that certain patterns emerge throughout the savanna, mainly depending on the climate.

Therefore, although the boundaries between the bioclimatic zones are of necessity, arbitrary, and some characteristics of savanna farming systems may cross these boundaries, particularly where soil conditions are favourable or irrigation is practised, it appears useful to consider each bioclimatic zone and its characteristic farming systems in turn.

Referring again to table 1 on p 10, some selected farming systems in each bioclimatic zone will now be described, starting with the sub-desert zone.

ARID SAVANNA ZONE



Chapter 3. SUB-DESERT ZONE

0-300mm Rainfall

0-60 Day Growing Season

Northern Sahel - West Africa

This is the transitional zone between the desert and the savanna. The zone borders on the Sahara and Kalahari deserts where mean potential evapotranspiration (normally more than 2000mm per year), greatly exceeds rainfall. The rainfall is generally insufficient to allow crops to be grown without irrigation, except in areas with ground-water or in unusually wet seasons. The zone is mainly used as grazing land by nomadic and transhumant herders, who have caused severe overgrazing in many areas in recent years.

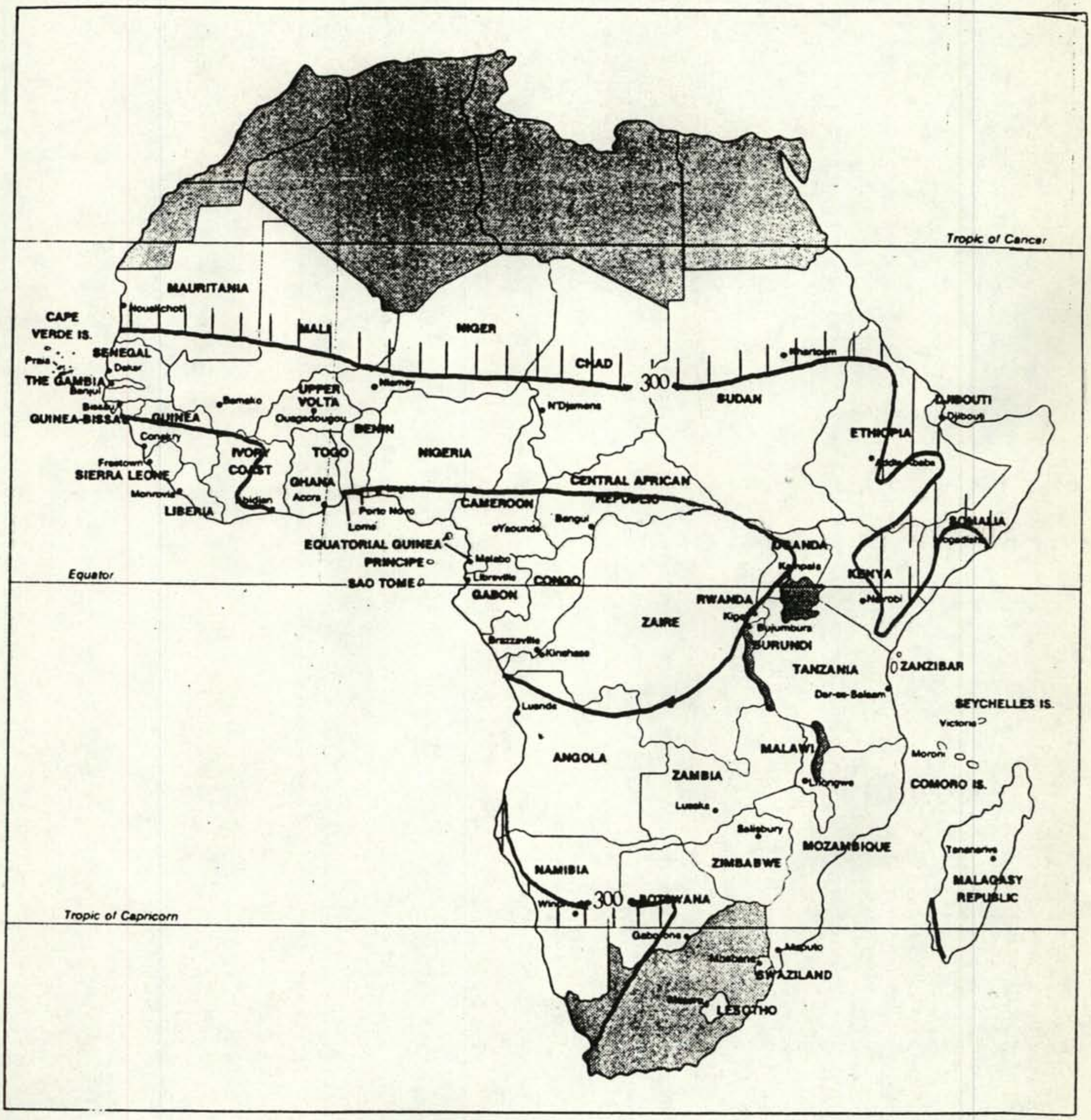
The dune sands which are widespread in this zone have a high infiltration rate, so the little rain which falls soaks into these soils rapidly. These soils are some of the most severely affected by wind erosion, and this is the zone where so-called "desertification" is occurring actively (Ridder et al. 1982).

Such vegetation which survives in this zone consists mainly of scattered Acacia trees, xerophytic thornscrub and other shrubs and herbs, and sparse ephemeral annual grasses which come up after the rains.

There are a number of large-scale irrigation schemes in this zone in various parts of Africa, including the mechanised rice scheme along the lower Senegal river in Senegal (Scudder 1980), the Office du Niger in Mali (de Wilde 1967), the Gezira scheme in the Sudan (Gaitskell 1959), Mwea-Tebere in Kenya (Chambers and Moris 1973),etc. There appears to be a considerable potential for the expansion of irrigation in this zone, but Scudder (1980) among others, has emphasised the high capital costs and severe management problems which have been encountered in many of these large schemes. Since they are outside the scope of this review they will not be discussed further here.

Towards the higher rainfall margin of the zone a few cultivators or herders may attempt to sow a crop of millet or cowpeas on the better soils after the occasional heavy shower of rain, but the failure rate is very high. Since the pastoral systems, which are important in this zone, are outside the scope of this review, the zone will not be covered here.

SUB-DESERT ZONE



Chapter 4. ARID SAVANNA ZONE

300-600mm Rainfall
60-90 Day Growing Season
Southern Sahel - West Africa.

This zone covers most of northern Senegal from Dakar to just south of the Senegal River, and extends eastward across Africa, including large parts of Central Mali, northern Burkina Faso, southern Niger, north-east Nigeria, Chad, Sudan, and Ethiopia. It extends into southern Ethiopia and as a narrow strip through Kenya into Somalia and central Tanzania. It is also widespread in southern Mozambique, Zimbabwe, and eastern and northern Botswana, extending into eastern Zambia and south-west Angola.

The vegetation in this zone consists mainly of Acacia spp., with Acacia senegal (gum arabic), Acacia vaddiana, Leptadenia pyrotechnica, Salvadora spp., Grewia spp., with Acacia seyal in low areas liable to flooding, and grasses such as Aristida and Chloris spp., common in the Sahel. In eastern Africa Commiphora spp., are also important. In the Sahel it appears that nearly all the trees have uses, either for fruit (Balanites aegyptiaca, Phoenix dactylifera), or for forage (Acacia spp.)(Okigbo 1986). The trees and bushes are heavily lopped for feeding livestock in the long dry season, when grazing is short.

Much of this zone has been affected by wind erosion in the past, and dune sands are widespread, though other soils of slightly higher productivity are also represented.

Agriculturally, it is an important zone. In West Africa a considerable part of it is occupied by cultivators mainly growing pearl millet, often with intercropped cowpeas, and by large herds of domestic livestock. Pearl millet appears to be particularly well adapted to sandy soils, and it will often give some yield even on soils of apparently low fertility. It is the dominant crop in the West African part of this zone, the Sahel. In West Africa, most of the millet varieties are photosensitive, and adapted to the latitudes where they are grown, so the crop usually matures about the end of the rainy season. Therefore in the northern part of the zone, earlier maturing varieties (called Souna in Senegal), which mature in 90 days are grown, whereas in the southern part of the zone, later varieties (Sanyo in Senegal), maturing in 120 days, fit the longer rainy season. In recent years a still earlier variety (called GAM in Senegal), produced by breeders to mature in 75 days, has become popular (Bilquez 1975).

4.1. Senegal

In Senegal millet is not usually intercropped in the north. Average yields are generally low, around 520 kg/ha. However, research on crop water requirements at Bambey, Senegal under improved agronomic conditions (heavy fertilizer application, full crop protection, etc.) showed that the three types of millet would give the yields shown in Table 5 if their average water requirements were met.

Table 5. Average crop water requirements and yields of millet varieties of Bambey 75, 90 and 120 day maturities at Bambey in Senegal (from Dancette 1978).

	Average water requirement in growing season mm	1973-77 Average grain yield (rounded) Kg/ha
120 day Sanyo millet	620	1600 - 2000
90 day Souna millet	430	2800 - 3000
75 - day GAM millet	350	1700 - 2300

In 1977, the Bambey rainfall of 374mm only provided 63% of the Sanyo millet requirement of 620 mm, and the crop failed, giving a grain yield of only 153 Kg/ha. Dancette has also plotted the probability of receiving sufficient rain for a 75 day GAM millet in northern Senegal, which shows clearly how risky millet production becomes in the northern part of the arid zone (Fig 9). Cowpeas of the same maturity length have a slightly higher water requirement, whereas groundnuts have about the same water requirement as millet.

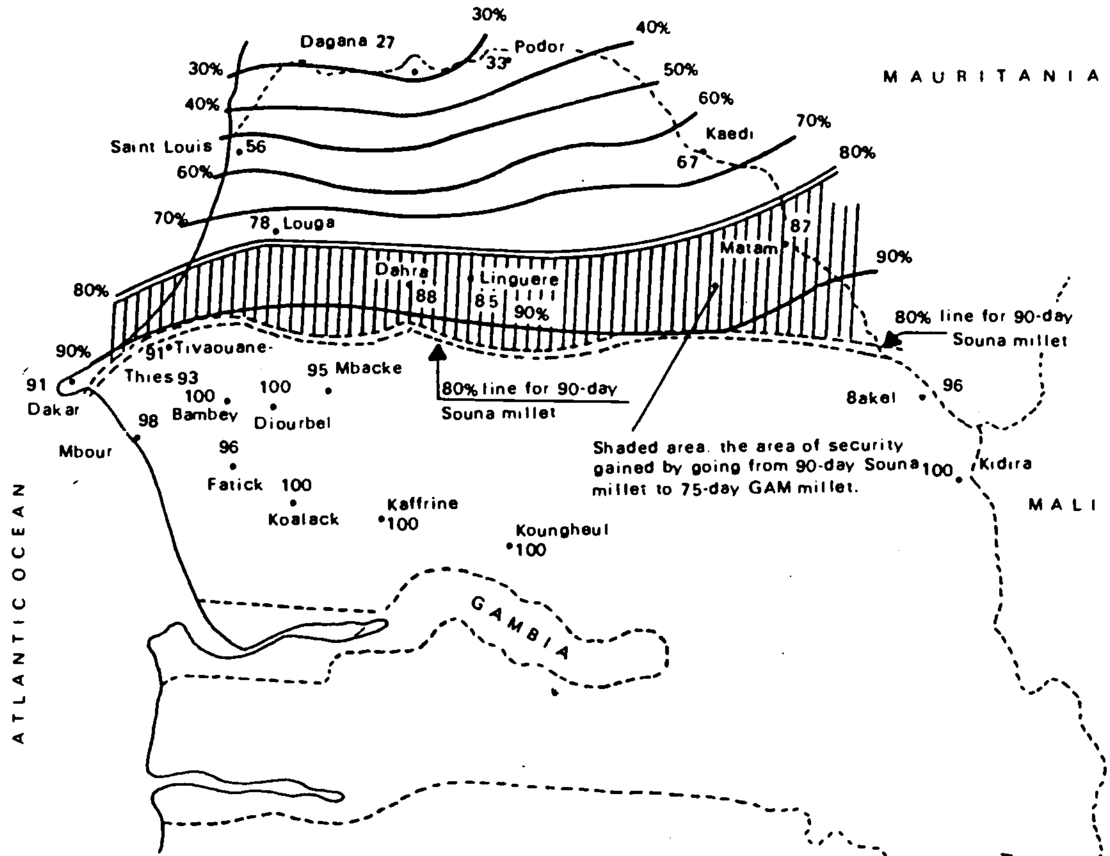


Fig 9. Lines of equal probability for favourable water conditions for a 75-day GAM millet in Senegal (Dancette 1978).

Data from Burkina Faso indicate similar trends there (Franquin 1978), and it appears that these results could be modified as necessary to be applicable throughout the sub-arid zone where millet is grown, but they should be checked by local research.

Other crops which are grown in the arid zone include cowpeas, often intercropped as already mentioned, groundnuts, and a limited area of sorghum, mainly on the heavier soils. Groundnuts are particularly important in Senegal, which has relied on their export for the greater part of its foreign exchange earnings for many years. The groundnut "basin" of western Senegal extends from the Louga area in the arid savanna zone about 200 km north of Dakar to the Sine Saloum region in the sub-arid zone about the same distance south of Dakar. In a year of good rainfall Senegal often produces over 1 m tonnes of unshelled groundnuts (Anthony et al. 1979 p45). Much research on the crop has been carried out by researchers of the French Institute de Recherche Huiles et Oleagineaux (IRHO), now a part of CIRAD, and more recently by the Senegalese agricultural research institute (ISRA). Like the millet, varieties have been bred with maturity lengths adjusted to the varying lengths of the rainy seasons in the country, so that 90 day varieties are grown in the Louga area in the north, 105 day types in the centre, and 120 day types in the south (Dancette 1978).

The farming system which has been developed by the farmers in Senegal's groundnut 'basin' appears unique, and has some particularly interesting features. Groundnuts need to be planted immediately after the first heavy rains, particularly on the dune sands which are widespread in northern Senegal. Any delay in planting can cause a severe reduction in yield. Therefore the cultivators prepare the land by a light hoeing during the dry season. Then virtually the whole crop is planted with single-row planters, usually horse- but sometimes donkey-drawn. It has been suggested that the farmers have adopted these planters, which are not used to the same extent elsewhere in Africa, simply to get the crop planted quickly. Usually the groundnuts are grown in pure stand, though occasionally a few cowpea seeds may be mixed with the groundnuts. The groundnuts are usually hand-weeded, or occasionally a light horse- or donkey- drawn weeder may be used. When mature they are pulled and left to dry for a few days, then the nuts are stripped from the haulms (probably the most laborious job), dried and stored for sale and the haulms are collected as hay and stored on the roofs of the houses. Groundnuts may be grown repeatedly on the same land, with 1 or 2 millet crops after 2 or 3 groundnut crops, depending on the cultivators' requirements. Much of the land appears to be continuously cropped. This rotation can be depicted as follows: (fig 10)

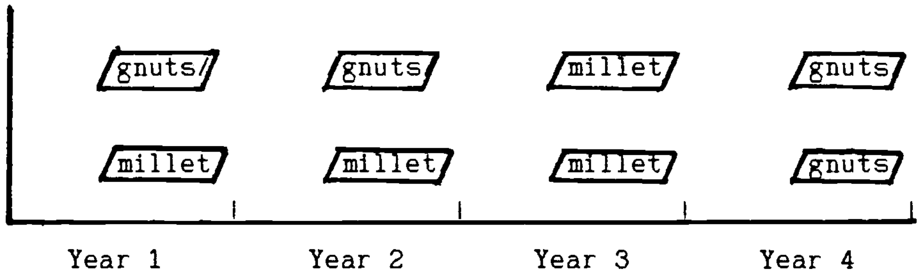


Fig 10. Millet and groundnuts farming system in Bambey region, Senegal.

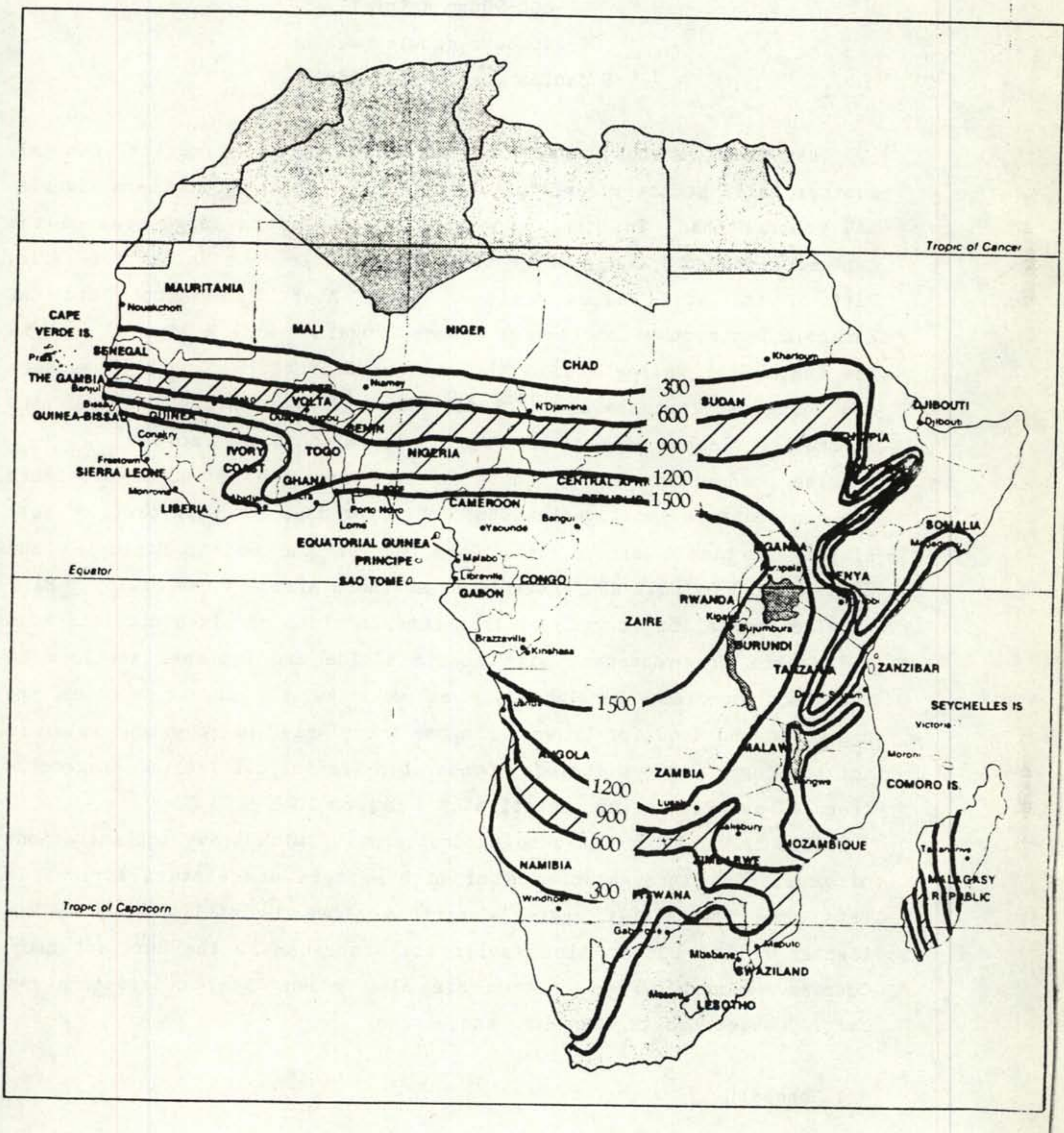
An interesting aspect of the farming system practised by the Serer people in the Bambey area is the preservation of the indigenous Acacia albida and Baobab trees. These give a park-like appearance to the country. The Acacia albida is unusual in that it sheds its leaves during the rainy season, and grows new leaves during the dry season, so crops grown under the trees are not shaded. Since it is a leguminous tree, the leaf-fall provides a substantial quantity of nutrients for the crops growing under the trees. The Serer also make considerable use of manure collected in the kraals where the livestock are penned at night, mainly using donkey- or horse-drawn carts. This is spread in the fields, starting near the homestead, with decreasing quantities reaching the farthest fields (Pelissier 1966). Some fertilizer (mainly phosphate) is also applied to the groundnut crop.

4.2. Tanzania

In Tanzania, a large area extending from the Masai steppe south of Arusha, through Dodoma and central Tanzania to Iringa, comes in the arid zone. It is interesting that one of the main sites for the ill-fated groundnut scheme at Kongwa is in this zone.

In Southern Africa the zone extends on both sides of the Limpopo river through to Mozambique, southern Zimbabwe, northern South Africa, and northern Botswana into northern Namibia.

SUB-ARID SAVANNA ZONE



Chapter 5. SUB-ARID SAVANNA ZONE

600-900mm Rainfall

90-140 days growing season.

Sudanian Zone - West Africa.

This zone extends from Dakar to include much of central Senegal, central Mali, southern Burkina Faso and Niger, most of northern Nigeria, and central Chad. In Sudan it expands to include a large area of the central rainlands, and some of the irrigation schemes on the Blue Nile. Part of the Rift Valley south of Addis Ababa in Ethiopia and the Karamoja District of north-east Uganda, together with a limited area in the Kenya Rift Valley and to the east of Nairobi, and much of western and southeast Tanzania are included. Most of western Zimbabwe and part of southern Zambia and southern Angola are also in this zone.

The predominant upland soils in this zone are alfisols, but there are considerable local variations, including dune sands in parts of West Africa, vertisols around Lake Chad and in the Sudan, Ethiopia, and Somalia, and oxisols and entisols in southern Africa (see Fig 8, p 21)

The vegetation in much of this zone consists of mixed combretaceous and Acacia tree savanna, with Acacia albida and Hyphaene thebiaca as indicator species. Parkia spp., as well as the former species are protected and used for browse. Mangoes are planted where ground water is not too deep. Grasses include Cenchrus ciliaris, c.biflorus, Eragrostis tremula, and Pennisetum pedicillatum (Okigbo 1986 p 98).

This is an important zone agriculturally, with heavy concentrations of population throughout much of both western and eastern Africa. In this zone the millet system described above is still found on the lighter soils, but on the heavier soils sorghum is the dominant crop. Cowpeas, groundnuts and cotton are also grown. Many cultivators own cattle, sheep, goats, donkeys, and horses.

5.1. Senegal

Considerable research has been carried out on improved farming systems in the Unites Experimentale in the Sine Saloum area in Senegal. This area appears to have been one of the first in West Africa to have adopted animal traction, in the form of ox-ploughs. Their use is now widespread in the southern part of Senegal, together with the horse- or donkey- planters described under the arid zone (p 46) which are particularly used for groundnut planting.

Ruthenberg (1980, p 150) comments "The commercialization of the area began about 1850, and it has accelerated in the last forty years. The traditional fallow system has been replaced by a permanent cropping system, with groundnuts as the dominating crop, which is unsurpassed in the area in terms of returns per hectare and per hour of work. The guiding principle of land use is a simple one. There have to be sufficient cereals for food (about 0.25 ha per person yielding 200 kg at a yield expectation of 0.8t/ha). 90-day pearl millet supplies early food, and 130-day sorghum supplies food later in the season. The rest is planted with groundnuts. Some rice is grown in valley bottoms. Farmers now tend to replace millet with early-maturing maize, which yields much more, produces green maize as food even earlier than millet, requires less threshing work, and no bird-scaring, and is simpler to store".

The Wolof people of this area usually live in fairly large villages, and family sizes are still quite large. Up to about 2 ha per person may be cultivated. As described for the 'ring' culture system (p 7), the land around the village is usually manured and used for maize and millet growing, while the land further from the village is used for groundnuts, often rotated with millet or sorghum, and sometimes cotton growing. Some artificial fertilizers are used, but because most of the land is permanently cropped, there appears to be a steady decline in soil fertility. Most farmers own some cattle, in addition to goats, sheep, donkeys, chickens, and perhaps a horse. The livestock are fed on communal grazing land and crop residues, and browse, including Acacia albida, is also fed in the dry season. The livestock are often herded by hired Fulani herdsmen, and are used for up to about 100 days work in the fields per year. Horse drawn passenger vehicles which are also used as taxis are common in this area.

5.2. Burkina Faso

In Burkina Faso, the zone includes the Mossi Plateau area around Ouagadougou, where major agricultural problems are developing. The Mossi Plateau is relatively densely populated, with up to 40 people/km, and the soils, which are mainly fine sandy loams, are often shallow over underlying ironstone gravel or plinthite. Heavy population pressure, overcultivation, and erosion have led to serious losses of topsoil and, in several areas, widespread denudation and exposure of the subsoil in the form of gravel or plinthite (de Wilde 1967, p370). It appears unlikely that some of these areas will ever carry a crop again.

Matlon (1984), an ICRISAT regional economist, carried out on-farm tests on a stratified random sample of farms in two villages in each of three distinct agroecological zones. One of these pairs of villages, with about 750mm annual rainfall, comes into the sub-arid zone. The stratification of the 25-30 farmers participating in each village was defined by the ownership or non-ownership of animal-powered equipment for cultivation. ICRISAT's objectives were to test "improved" technologies (mainly high yielding varieties) produced on the research station, under farmers' conditions to determine their technical adaptation and farmer acceptance or otherwise. As in Senegal, sorghum is the dominant crop in this area, with millet important on the lighter soils. Under normal farmer management, the local sorghum varieties gave average yields of 189 kg ha-1 on the shallow plateau soils, and about 600 kg ha-1 on the slightly deeper soils further down the slope. Some tests were carried out in 1981 comparing the local and some improved sorghum varieties with the local recommended practices of preplanting ploughing and 100 kg fertilizer (14N, 23P, 15K/ha). Table 6 summarises the results.

Table 6. Mean grain yields of local and improved sorghums by position down the toposequence at 2 levels of management, Nakomtenga and Nabitenga villages, Burkina Faso, 1981.(from Matlon 1984, table 3 ,p 105)

	Farmer Management Kg/ha				Improved Management Kg/ha			
	E35-1	38-3	CSH5	Local	E35-1	38.3	CSH5	Local
Plateau	-	318	144	189	-	185	813	273
Upper slope	268	305	773	605	966	1048	1256	1101
Mid-slope	685	311	537	626	1405	915	1369	1197
Lower slope	810	516	602	606	1389	1106	1202	1150

The results suggested that there was little yield advantage for the farmers in growing the improved varieties using their normal management on the plateau and upper or mid slopes, and only a small advantage with E35-1 on the lower slope. The extremely low yield levels (between 144 and 318 kg ha-1) on the plateau soils, which are the most widespread, with all varieties under farmer management, and with all except CSH5 under improved management, are striking. It would be most interesting to know how low the yield has to fall before the farmer decides the crop is not worth growing. With improved management (ploughing and fertilizing), the hybrid CSH5 gave a higher yield on the plateau, and both E35-1 & CSH5 gave small yield increases on the mid and lower slopes. Interestingly, some farmers decided to use farmyard manure as well as fertilizers in the tests, and these farmers achieved gross margins with the improved variety E35-1 nearly double those with the local variety. With fewer inputs, the local variety often gave a higher gross margin than the improved one. Matlon (1984, p 108) summarised part of an economic analysis of these results as follows:

"The results...clearly demonstrated the high risks associated with fertilizer use in semi-arid conditions under farmers' management. Thus, even with mean financial returns of 77% and 42% in the high- and middle-rainfall zones, the percentages of fields where incremental yields did not cover subsidized fertilizer costs were 44 and 70 for the local varieties. Costing fertilizer at its unsubsidized price found average negative returns for all cases except improved sorghum varieties in the high-rainfall zone and under lowland conditions in the lowest-rainfall zone. An important question left unanswered was whether the recommended dose (100 kg/ha) of the available NPK fertilizer was the optimum dose. A farmers' test was subsequently designed to address this question".

Although further analysis of the enormous quantities of data collected in these case studies should yield considerable interesting information, and some highly detailed studies of this type are obviously desirable, it is difficult to determine to what extent the results can be extrapolated to other areas of Burkina Faso in the same bioclimatic zone.

Lang and Cantrell (1984) have described some of the work of the Purdue Farming Systems Unit in Burkina Faso. Their principle findings were:

"In two villages on the central plateau, and in half of the sample village on the edge of the plateau, the farmers are clearly oriented toward subsistence. They claim to ignore price in cropping and in deciding when to sell their crops. Their sales are strictly residual, prompted only by 'urgent need', regardless of the market price. If, as harvest approaches, their stocks are adequate, they sell grain to purchase small ruminants, which are kept for sale during lean years. The data documented the farmers' reliance on livestock sales as a principal source of revenue to purchase grain. Thus, the farmers are not. by plan, part of the cash economy.

Although the principle grain crop in all three villages is millet, farmers would like to plant more sorghum because sorghum stores twice as long (3 - 4 years) as millet (1 - 2 years) and, during good years, yields more than millet. They plant less than desired quantities because the variability in yield of sorghum and therefore, production risks are much higher than those associated with millet.

Labour, as has frequently been observed in other studies, is often a binding constraint durng the first weeding but is slightly more available during the second weeding.

Millet plantings are highly and consistently correlated with the number of active labourers/household. Sorghum plantings are confined to land that is more fertile or has better water retention.

Use of draft animals is profitable in the land-abundant zone because of intensification effects, and on the central plateau where extensification is possible. On the plateau, no intensification effects were detected.

In two villages, the farmer-managed millet trials showed statistically significant ($P<0,05$) yield responses to phosphate in the seed pocket and to tied ridges. The most promising treatment was a combination of the two techniques. For one village, average yield increases easily covered cash costs and provided returns to labour of about 28 CFA/work hour [about US$0.10]."

5.3. Nigeria

A considerable amount of farming systems analysis has been carried out by many researchers in northern Nigeria. (c,f. Ouedraogo et al. 1982, Kowal & Kassam 1978, Jones & Wild 1975, Norman et al 1976, etc.)

A particularly important feature for the purposes of the present study, and indeed for agricultural development throughout Africa, is the sustained intensification of smallholder rainfed agriculture which has been achieved in some areas of high population density. For example, Grove (1961 p 125 on) has described the land use situation in a heavily populated area;

"Northern Katsina: Dense settlement, land impoverishment and emigration - Towards the central districts of the Kano region population densities increase, and all the inner agricultural zones surrounding villages have a greater radius. The proportion of village lands under yearly cultivation is larger, and at some critical figure of population density the outermost zone of bush fallow farming is eliminated from the land-use pattern as a continuous feature. This critical figure varies with the soil conditions but it is probably of the order of 150 or 200 to the square mile [58 to 77 km-2]. Where population densities are lower than this, land use is commonly unspecialized; land is not used for different purposes according to its inherent capabilities, but any particular patch may be under woodland at one time, rough-grazing at another, cropped for a few years and then abandoned. In more heavily settled areas, there is a closer relation of the land-use pattern to soil conditions".

Hill made a detailed classic study of the village of Batagarawa which is 10 Km south of Katsina. She pointed out that, unlike Bindawa, at the time of her work in 1967, population densities in this area were not so high that bush-farms (farms which included some land under bush-fallow) had been entirely eliminated from the agricultural landscape. Also at that time much of the bush-land within 3-4 km of the village was still uncultivated, apparently because it was surplus to the farmers' requirements (Hill 1972, p 13.)

The 1967 population was made up of 386 men, 399 women, and 610 children, 1395 in all, of whom about 1,103 lived in the walled village (Hausa: gari) and 232 in dispersed farm houses. 1226 people (88%) made up 171 farming-units each headed by a farmer, and the remaining 64 people made up the households of the 4 ruling families (Hausa: masu-sarauta). Half the population was in farming units of 6 - 10 people, but as many as half the 'heads of farming units' were single handed farmers. Four farming units were much larger, with 20-30 members each. The main crops were sorghum, pearl millet (both early and late varieties). cowpeas, and groundnuts. Subsidiary crops included tobacco, sweet potatoes, cassava, local vegetables, rice, henna, hemp, and various tree fruits and seeds (particularly locust beans, Parkia filicordea).

Hill (1972 p20) makes the important observation that the manured farms around the village are continuously cultivated, normally without any fallow period, even though the farmers have access to bush farms and uncultivated land within a short distance. She describes the manuring practices.

"Despite the fact that land is plentiful,individual farmers prefer to concentrate their farming in the manured zone, and some of the most successful of all farmers do not trouble to cultivate any bush-farms. The main types of manure are compound sweepings, including the droppings of small livestock (sheep, goats and donkeys), which are of fundamental importance in this economy, and cattle dung which is partly provided by cattle owned (or cared for) by Batagarawa people ...., partly by non-resident Fulani pastoralists who are paid for bringing their cattle to graze on the farms after harvest. Imported chemical fertilizers are very popular, and increasingly applied, but are as yet of little importance relative to natural manures, including latrine manure".

If Hill's conclusion is correct, that the Hausa have developed a farming system which maintains soil fertility under continuous cropping, the implications could be important for many areas elsewhere in Africa with similar climate and soils.

Norman et al (1981 p 52) point out that the traditional cropping system in many parts of the West African savanna involves the permanent cultivation of some fields, usually near the house compound, and the maintenance of soil fertility through manuring. Fields further away are cultivated for a few years, after which soil fertility is restored primarily through fallowing. The fields near the compound are usually common fields used for food crops, whereas the fields further away which are cultivated intermittently may be used more for "cash" crops. They continue;

"Increasing land shortages concomitant with rising population densities are resulting in an increase in the production of permanently cultivated fields, and the remaining fields are being left fallow for progressively shorter periods.... Traditionally livestock herders and sedentary crop farmers have had some symbiotic relationships in which manure for fields is an important element....... Although with the problems of continuing this complementary relationship in the face of progressive decreases in grazing land, there is also the question of whether such a relationship can provide the increasing amounts of organic fertilizer required to maintain soil fertility. It has been noted that, apart from a few exceptional areas such as that around Kano in northern Nigeria ...., the decrease in yields has not been forestalled. This problem has been of particular concern in the francophone countries, where the introduction of animal traction has been seen as a means of alleviating such problems .

In general there appears to have been an assumption on the part of researchers responsible for developing improved technology that all fields are viewed in the same way by farmers. The above observations concerning the "ring" cultivation system [see fig.... above] appear to repudiate this assumption, although the implications for development of relevant technology are unclear. One would expect, for example, that the fertility would be an important issue with reference to fields close to residential areas, which are also likely to have increased Striga infestation due to the continuous cropping of cereal crops. On the other hand, labour efficiency is likely to be more important in more remote fields, but mechanization problems are likely to be greater there because fields often have not been adequately destumped."

Various methods of using livestock to increase manure supplies on the permanently cultivated land near the compound were traditionally practised. Where the cultivator owned and managed his own livestock, he sometimes did this by moving the night boma from time to time, and cultivating the land so manured (Ruthenberg, 1971, p 66). Where the cattle were owned or managed by itinerant herdsmen, usually Fulani, the cultivator might provide crop residues, water, or even money, to encourage them to herd their cattle for varying periods in the dry season on the cultivated land, usually near the homestead.

Mixed cropping is an important practice throughout the savanna, which has sometimes been criticised as possibly reducing production and labour efficiency. Labour requirements and yields for sole and mixed crops at Sokoto in northern Nigeria have been measured by Norman et al (1979). (Table 7).

Table 7. Comparison of sole and mixed crops on rainfed land. Sokoto, Northern Nigeria. Annual average rainfall- 752mm.

	Sole crops	Mixed crops
Labour (man-hours ha-1)		
Annual	425.8	485.6
Labour peak period	232.5	238.0
Yield (Kg ha-1)		
Millet	736	686
Sorghum	652	122
Groundnut	429	188
Cowpea		56

Although there was a reduction in yield per hectare from each crop when the crops were mixed, The results in this study showed that there was approximately a 25% increase in the net value of the production and in the net return to labour from intercropping.

5.4. Cameroon and Chad

Burnham (1980, p150) has described the farming systems of the sedentary Fulani, Guiziga, Tupuri, Masa, and Kera peoples of northern Cameroon and Chad. Here, sorghum is the staple crop and at least thee main types are grown; early ripening 'wet-season red' sorghums, later ripening 'wet-season white' sorghums, and 'dry-season transplanted or muskwari' sorghums which are sown in seedbeds towards the end of the wet season and transplanted on the seasonally flooded clayey soils (mainly vertisols) of the Lake Chad basin as the flood recedes. These soils retain sufficient moisture into the dry season for a successful crop. Although the cultivation techniques are more labour-intensive than those for wet-season sorghum, they come later in the season so they do not compete for labour at the peak period for the wet-season sorghums.

A few people in this area may also grow early finger millet (Eleusine coracana) to obtain an early harvest after the 'hungry gap'.

5.5. Sudan

Further east, in the Sudan, the sub-arid zone is characterised by large areas of sorghum grown on the "black cotton soils" (Vertisols) of the central rainlands. In recent years an important development in this area has been the allocation of quite large blocks of land (averaging 400 ha) to certain wealthy individuals who use tractors to cultivate the land for sorghum growing. (Bunting 1987, personal communication). There appear to have been hopes among some of the Arab countries around the Persian Gulf that the Sudan could become the bread-basket of the Middle East, but these hopes have not materialized yet.

In Eastern Africa the areas near the equator which receive a total of 600 - 900 mm of rain have two rainy seasons per year.

5.6. Somalia.

For example, in southern Somalia a considerable area around Baidoa receives an average of between 600 and 700mm. Usually the first more reliable rains fall from about April to June, then there is a dry season of about 4-5 months, and the often unreliable second rains may occur in November - December. The problem in this situation is that neither rainy season is sufficiently reliable in quantity or distribution to produce a crop, so production is uncertain at the best of times.

Fortunately, there are large areas of dark cracking clays (vertisols and alluvial deposits), in this part of Somalia, which appear to have a high water holding capacity. The Somali cultivators have developed their own system of making a checker-board of small ridges to retain the limited rainfall. Sorghum is grown in the basins which are formed, and in a year of average or above-average rainfall a reasonable crop can be harvested. Where they are well maintained, these basins probably also help to prevent erosion, but the crop failure rate in seasons of below average rainfall can be high. The cultivators sometimes try to plant a second crop in the second rains, but the yields are usually low and the crop may fail as often as 1 year in 3. For example, in 1986 much of this area did not receive any rain at all in the second rainy season, so all crops failed. and severe hardship was caused to many people in early 1987.

One way in which the cultivators have attempted to respond to this uncertainty is by ratooning their first rains sorghum crop, in the hope that the regrowth may produce some grain in the second rains. Yields obtained by this method appear to be generally low, and it may also contribute to the carry over of stem-borers which often cause severe damage to the crop. Population pressure on the better soils appears to be increasing, and deficiencies of certain nutrients, particularly phosphate, are widespread. Some of these soils have a high phosphate fixation capacity, so heavy and uneconomic broadcast applications were sometimes found to be necessary to increase yields. Recently it has been found that good responses can be obtained from small phosphate applications placed near the seed at planting.

The cropping sequence here can be shown as follows:-(fig 11)

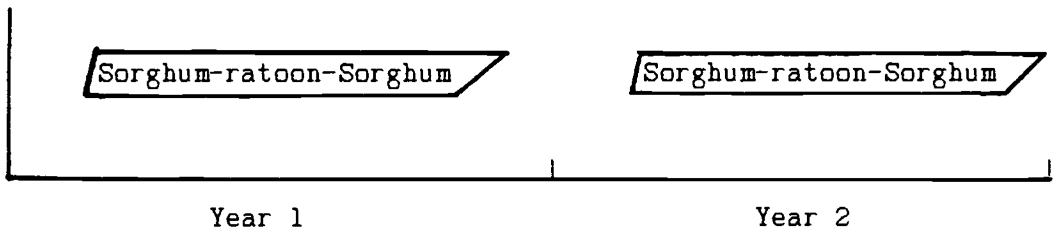


Fig 11. Cropping sequence in the Baidoa Region, Somalia.

Few other crops except sorghum appear to be grown, though some cowpeas may be planted in pure stand. Attempts have been made to introduce cotton growing with some success.

As elsewere in the arid and sub-arid zones, the most widespread agricultural activity in Somalia is livestock keeping. Many of these belong to nomadic or transhumant herdsmen, who often move to and from the Ogaden area of Ethiopia with their herds, depending on the availability of grazing and water supplies.

Although Somalis have cultivated sorghum for many years, many relied mainly on their livestock for their food supplies. In recent years an increasing number have taken to growing some sorghum while maintaining their livestock, which are taken to the traditional seasonal grazing area by some of the young men of the family. Despite the large numbers of potential draft animals, animal traction is little used in Somalia.

The two important rivers in the south of the country, the Shebelle and the Juba, are being increasingly used for irrigation, particularly of maize and sorghum. There are also limited areas of plantation crops, principally bananas for export, sugar cane, and some citrus and other crops.

The limited areas of Kenya, north-east Uganda, and the large part of Tanzania which come into the sub-arid zone are also mainly characterised by having two rainy seasons, or in southern Tanzania by a bimodal rainfall becoming more unimodal in the extreme south. Virtually all these areas are situated at about 800-1200 m altitude on the East African plateau. Therefore the lower temperatures, and in some localities, higher humidity, reduce the evapotranspiration rates so that the rainfall is more effective than at lower altitudes, provided that runoff is controlled. But the problems of two rainy seasons, neither of which may be consistently sufficient to produce a satisfactory crop, remain severe.

5.7. Uganda

For example, in the Karamoja district of northeast Uganda, as in the Sudan and Somalia, the main crop grown is sorghum, and the soil-type in much of the cropped area is a black cracking clay (vertisol). Ox - ploughs are widely used for land preparation, as many as a dozen teams often working on contiguous plots at the beginning of the first rains. The sorghum is planted, weeded, and harvested by hand, and the crop is stored on the head in traditional granaries. A little maize and cowpeas may be planted on the lower slopes of valleys where groundwater may be available. Usually little attempt is made to grow crops in the second rains, which are short and unreliable in this area, as in Somalia.

Traditionally, like the Somalia, the Masai, and other pastoral people, the Karamojong were transhumant pastoralists. As elsewhere, the increasing human population has necessitated keeping a number of animals which exceeds the carrying capacity of the pasture under the unrestricted grazing system. This led to severe denundation of the cover of palatable grasses and other vegetation, leaving bare soil which became seriously eroded. Inedible xerophytic plants such as Sansevieria and thorn-bush spread into some of these areas, further limiting the potential grazing land.

One of the valuable series of catchment research projects started by the now-defunct East African Agricultural and Forestry Research Organisation (EAAFRO), in the 1950's was established at Atumatak near Moroto which has a mean annual rainfall of 753mm. (Pereira et al. 1962, Blackie et al. 1979) It collected useful data on land and water management in that area, and showed clearly that the livestock carrying capacity of the land could be increased by some simple grazing management practices which maintained a cover of indigenous grasses on the land. This ground cover had the effect of reducing the runoff, which was found to amount to about 14% from overgrazed bare soil, to about 7% or less under improved grazing management (Blackie et al. 1979, p 185).

5.8. Tanzania

Ruthenberg (1980, p 96 on) has described the farming systems of Sukumaland, northern Tanzania. Traditionally, these were characterised as semi-permanent systems, with R values between 30-70. He suggested that an R value of 50 was typical, where 50% of the land was under crops. That is, three, five or ten years of cropping were usually followed by about the same lengths of fallow. Soils are mainly sandy alfisols, not high in fertility. The cropping systems are based on sorghum, sometimes partly replaced by maize, and "cash" crops such as cotton are important, leading to considerable increases in the area cultivated per farmer. Seasonal swamps and swamp fringes may be cropped with rice or sweet potatoes, and are also important for dry season grazing.

Previously the soil was still mainly cultivated with the hoe, and large ridges 1.3 - 1.5 m apart were made. Ox ploughs were coming in gradually, and there was some tractor-ploughing. As soil fertility declined after 6 - 8 years of cropping with cotton and cereals, the last crops would be millet or cassava, after which the land would go back to rough grass fallow for 6 - 8 years. The livestock would be grazed on the grass fallow and on communal grazing land during the cropping season, and on crop residues and seasonal swamps during the dry season.

In 1976 the population was villagized, and now farmers have to walk an average distance of 2.7 km from their homes to their plots, which takes them about 1½ hours there and back. Increasing pressure on the land has caused a decrease in the fallow period and a decline in soil fertility, so that cotton and cereal growing have been reduced and cassava, which can tolerate low fertility, has increased.

Perhaps Rounce (1949) summed up the position succinctly

"A situation of over-populated villages and impoverished soils must be passed before better husbandry can spread."

5.9. Zambia

Anthony et al. (1979, p 179) have analysed the farming systems in Mazabuka district, near the Zimbabwe border, which has a mean rainfall of about 840 mm per year in one season. They comment as follows:

"Mazabuka farmers have worked beside European farmers for seventy years, and many of them have at one time or another worked for European farmers. The first Europeans to farm in Zambia relied on draft oxen, and Tonga farmers learned the practice from them. Later, when the Europeans adopted tractors and trucks, African farmers bought their used ox-drawn equipment and sometimes their trained oxen, but it was not long before some of them owned tractors and light delivery vans, too. European farmers constituted a large enough market for purchased inputs to support agricultural supply firms, which supplied black and white farmers alike with seeds, chemicals, and farm tools.

In 1967 the Mazabuka District presented a picture of active and comparatively rapid agricultural change that had its roots in the early century. An increased demand for maize, which coincided with the availability of ox-drawn implements, made for an increased acreage of the maize crop. During this early period a familiar pattern of agricultural development emerged. Increased agricultural output was achieved by the expansion of acreage and yields remained low.

Alienation of land, natural population increase, and a tendency to move to fertile soils along the rail line and near markets led to localized high population densities. At the same time there was a rapid buildup of Tonga cattle herds, which resulted in overstocking in some areas. This led to a government soil conservation program. The major works put in, and particularly the provision of cattle-watering points, benefitted all farmers.

The Tonga are a strongly individualistic people and there are no strong barriers to inhibit personal initiative. Taking the opportunity presented by the availability of a market for maize, a small class of comparatively large farmers had emerged by the late 1940s, and some were already selling several hundred bags of maize. By 1950 a few had gross incomes of £1,000 or more per annum . Most of this came from the sale of maize, but poultry, cattle, and pigs provided important secondary sources of income. A few farmers had invested in trucks and one or two in tractors, with which they did custom ploughing for their neighbors. With the incomes obtained from farming, capital investment in farms continued. This took the form of better housing, wells, the occasional windmill, fencing, implements, and machinery.

In the 1960s, farmers were introduced to major technical innovations, hybrid maize seed, and a new cash crop, cotton. With the use of hybrid varieties and fertilizer, yields of thirty to forty bags (200 pounds-90kg) per acre [equivalent to 6-8 t ha-1] became obtainable. The two inputs, double hybrid seed and fertilizer, cost about £9 per acre [US$67 ha-1] at the recommended rate. However, the survey showed that substantial and increasing numbers of Tonga were purchasing both inputs, and that individual farmers were getting yields of over twenty bags (1.8 t) per acre [4.5 t ha-1]. The wider use of these innovations was stimulated by the provision of substantial credit and facilities for marketing and the purchase of inputs."

Farmers were slower to adopt cotton growing,as they were unsure whether the crop provided a better return to investment than maize.

Anthony et al (1979, p 181) continue;

"Agricultural change among the Plateau Tonga over the last sixty years has been impressive, whether measured against the situation existing at the beginning of the century or against the experiences of other African savanna areas, and in recent years the contribution made by agricultural scientists has been of key importance. The Tonga farmer has responded readily to economic incentive. Future development in the area will depend on the availability of markets for Tonga produce. At present the district is essentially a one-crop area, but sales of cattle and milk provide substantial additional income.

A controversial aspect of development in the area is the extent to which assistance should be provided for tractor mechanization on small-and medium-scale farms. A minority of Tonga farms in Mazabuka District are large enough for the economic use of tractors, and there are others that would benefit from the use of seasonal tractor hire for land preparation. However, this is a situation that is best left to the enterprise of the Tonga themselves. Past development suggests that, as the need arises, the wealthier farmers will purchase tractors for private and contract work. Government assistance can most effectively be provided by helping the tractor owners and their employees to obtain adequate training in the maintenance and use of their equipment. Easy credit for the purchase of tractors, or a subsidized rate of tractor hire, is likely to result in inefficient use of expensive equipment and waste of farmers' resources."

5.10. Summary

The sub-arid savanna zone forms a part of the main cereal-producing belt of Africa. In West Africa it has been traditionally characterized by the production of sorghum on the heavier soils, with some pearl millet on the lighter soils. These dominant crops are usually planted mixed, often with cowpeas, which are planted at low density, mainly for forage for livestock, but also for grain. Most farmers plant a sufficient area of cereals (usually about 0.2-0.3 ha per person), to provide the basic subsistence diet, and add a 'cash' crop, usually groundnuts in Senegal and Nigeria, but cotton in some areas. These are grown in rotation with the cereals.

Farmers often plant small plots of maize, sometimes mixed with millet or sorghum, on the manured land round the homestead or village. This maize usually produces the first food after the 'hungry gap' in the form of green cobs, but maize is more susceptible to drought than sorghum or millet. On the heavier soils, particularly where manure and/or fertilizer are available, additional maize may be planted, usually partly replacing sorghum, or mixed with it. Small plots of rice are often planted in the seasonally flooded swamps.

This pattern extends across West Africa from Senegal as far as Chad, and includes much of the 6 million ha of sorghum in northern Nigeria.

Many farmers throughout this zone own livestock, mainly cattle, sheep and goats. Cattle are used for ploughing, and horses and donkeys are used for transport, and in Senegal and Burkina Faso, for planting groundnuts and cultivating. Livestock are often herded by paid herdsmen, frequently Fulani, who may receive payment in milk or in other forms. Where population pressure is heavy, so that continuous cultivation is practised, as in the 'groundnut basin' of Senegal, and around Kano in northern Nigeria, farmers have attempted to expand their manured area. They may do this by moving the cattle boma around the fields, or by paying or otherwise persuading the Fulani herdsmen to tether their cattle on the stubble in the dry season.

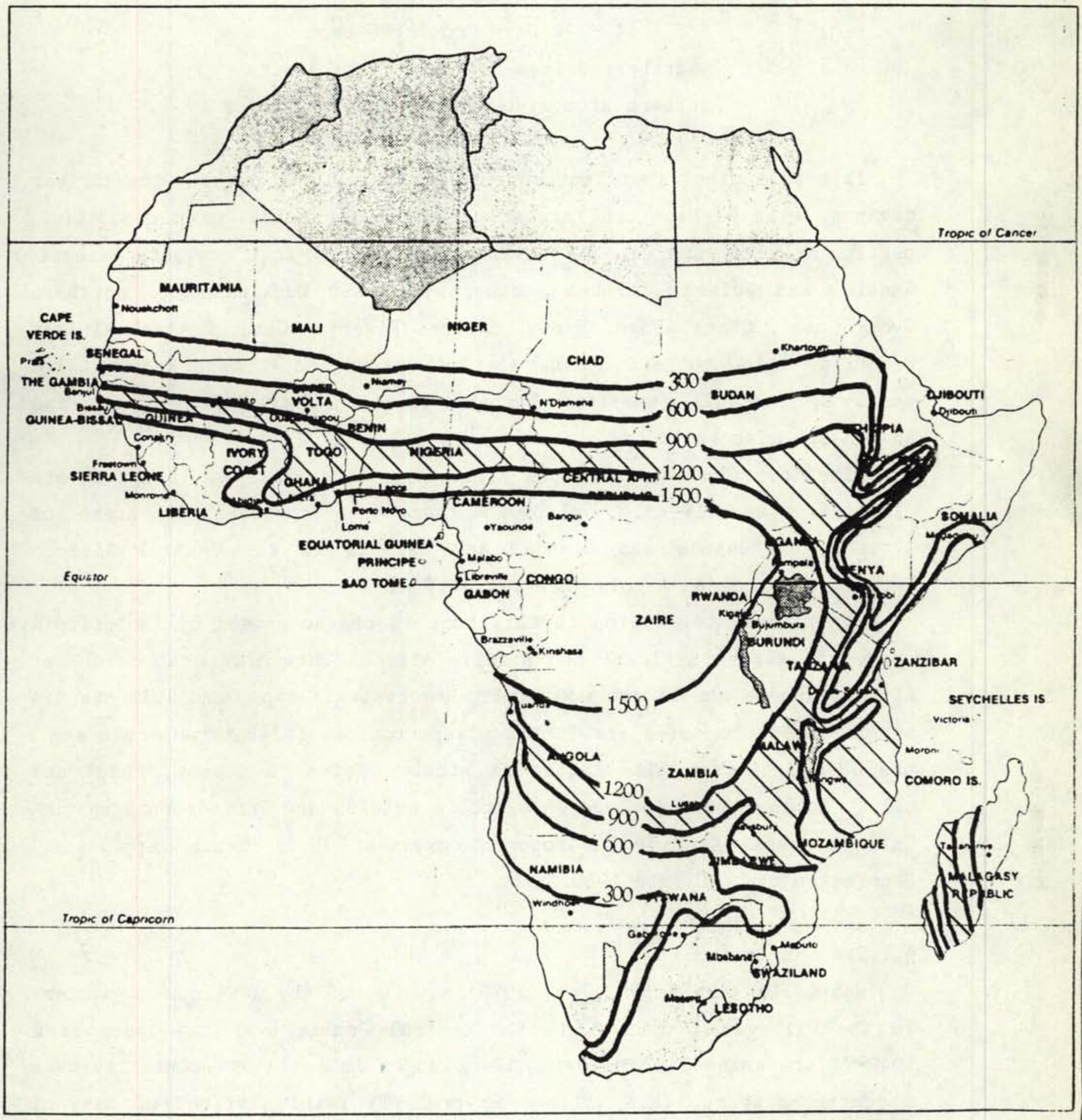
Although some phosphate fertilizer is applied to groundnuts in Senegal, and both phosphate and nitrogen are used on cotton and maize, little fertilizer is applied to the sorghum or millet crops, though they may obtain some benefit from the phosphate residues after maize, groundnuts or cotton.

In areas with heavy population pressure, such as the Mossi Plateau in Burkina Faso, parts of the Senegal groundnut basin, and parts of northern Nigeria, severe soil impoverishment and erosion are taking place.

In the sub-arid areas of the Sudan, Ethiopia, Somalia, north-east Uganda, and Tanzania, dark-coloured cracking clays (mainly vertisols), are widespread. Sorghum, mainly planted in pure stand, is the principal crop in these areas, though a little maize may be grown. In Sukumaland, northern Tanzania, cotton is an important 'cash' crop, and rice or sweet potatoes are planted in seasonal swamps or swamp fringes. Cassava is increasingly planted where soil fertility is declining.

In southern Africa maize appears to have replaced sorghum throughout much of the area, but sorghum is still widespread in the drier parts of western Zimbabwe and Botswana..

SUB-HUMID SAVANNA ZONE



Chapter 6. SUB-HUMID SAVANNA ZONE

900-1200mm Rainfall

140-190 Days Growing Season

Northern Guinea Savanna - West Africa

Northern Miombo Woodland - Eastern Africa

This is another important zone agriculturally throughout the African savanna, with perhaps the largest potential for annual crop production, particularly cereals, in the savanna. It extends from southern Senegal, Gambia, and Guinea, through southern Mali and Burkina Faso, northern Ivory Coast, Ghana, Togo, Benin, central Nigeria, Chad, Central African Republic, into southern Sudan, most of Uganda and western Kenya. Large parts of Tanzania, northern Zambia, southern Zaire, Mozambique, and Angola are also included.

Like the sub-arid zone, the soils in a large part of this zone are classified as alfisols, although there are considerable areas of ultisols in Guinea and Uganda, and oxisols in the Central African Republic, Zaire and Angola (See fig 8, p 21).

The natural vegetation in this zone is characterised by Isoberlinia spp., and Burkea africana and Afzelia africana are also common in West Africa, and in the miombo woodlands, Brachystegia spp., and Julbernardia spp. Protected species are Parkia clappertoniana and Butyrospermum spp., the Shea Butternut. The latter is widely used as a source of fat and oil. . Timber trees include Chlorophora excelsa and Entandrophragma spp. Tall grasses include Andropogon gayanus, Hyparrhenia spp., and Pennisetum spp. (Okigbo 1986, p98).

6.1. The Gambia

Haswell's (1953, 1963, and 1975) studies of the development process in the village of Genieri in the central Gambia over the years from 1949-74 are unique in following the changes in a village community over a quarter-century. This village is probably fairly typical of many of the Gambian villages which border the Gambia River, and of villages in the neighbouring Casamance and Sine Saloum regions of southern Senegal which border rivers in that country. But the increasing importance of rice cultivation in Genieri means that it is not typical of villages on the region which rely entirely or mainly on rain-fed agriculture. The farming system in Genieri is shown in Fig 12.

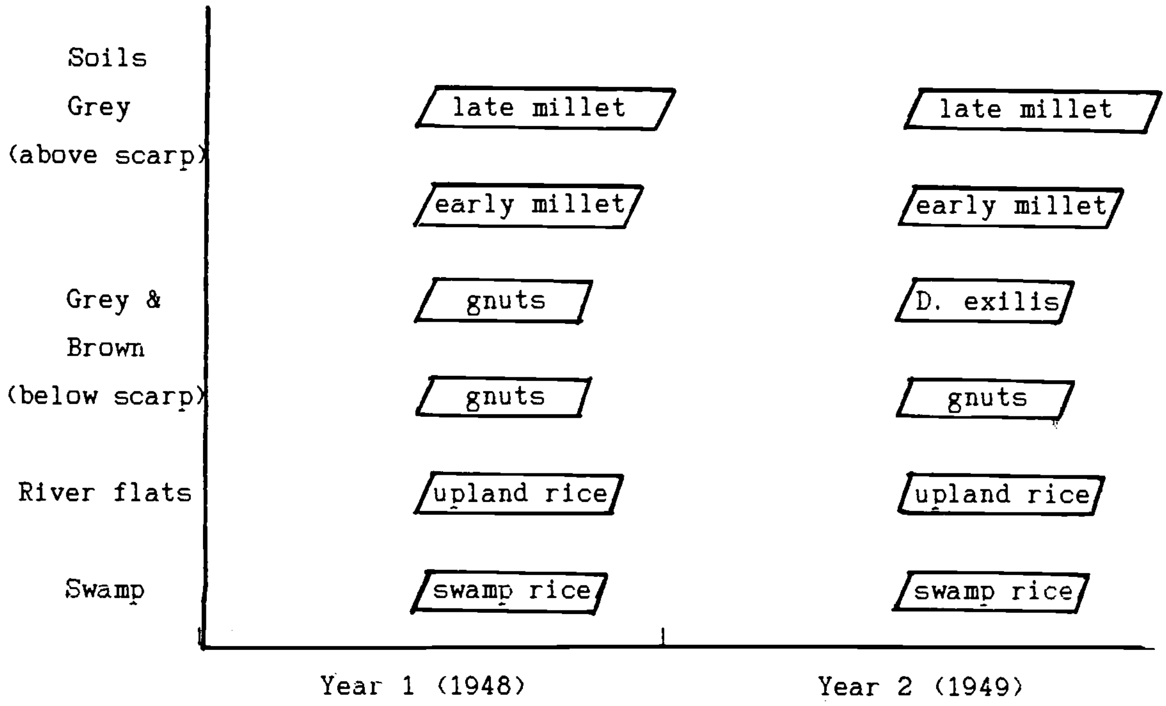


Fig 12. Groundnut-millet and rice systems at Genieri village in the Gambia during 1948 and 1949 (From Haswell 1975, p 43 on).

In this village groundnuts and a little early millet were grown by individual men, mainly on the more fertile brownish sandy loam soils near the village, whereas late millet was grown communally by the men after clearing bush on the less fertile grey soils above the scarp. Women were entirely responsible for both upland and swamp rice which provided about 80 % of the village's food grain supply. Table 8 indicates the land and labour use for the crops in 1949, for this village of 483 people, (220 males and 263 females.).

Table 8. Land and labour use and crop yields, Genieri 1949.
(Derived from Haswell 1953, pp32 and 39.)

	Total Area ha	Average plot size ha	Average yield kg/ha (1)	Average hours labour/ha (all operations) (2)	Average Returns to labour kg/hour
Guinea savanna					
Grey soils					
(above scarp)					
late millet	35.8	1.15	256	544	0.47
Grey & brown soils					
(below scarp)					
early millet	5.7	0.63	319	660	0.49
sorghum	4.1	0.48	177	166	1.07
Digitaria (3)	32.6	0.43	115	116	0.99
maize (4)	2.3	0.06	-	786	0.91
groundnuts	105.8	1.05	541	650	0.83
River flats					
upland rice	28.0	0.17	340	2051	0.17
swamp rice	69.7	0.32	991	1534	0.64

Notes:
(1) Yields: Cereals - grain, groundnuts - in shell, rice - paddy.
(2) Labour: Millet, sorghum & groundnuts - men, Digitaria, maize, and rice - women.
(3) Digitaria exilis -"hungry rice" grown in rotation with groundnuts.
(4) Maize - grown in house compounds to take advantage of refuse and dung. The maize cobs are usually eaten green.

Haswell (1975, p 42) points out that the average return to labour from groundnuts in 1949 was 0.83 kg per hour. More work put into the crop would probably not have increased the return much. Since land was not an overall limiting factor, though there was some shortage of the more fertile brown soils near the village, she suggests that returns to labour were more important than yields per hectare. However, she points out that :

"In traditional farming practice, labour was virtually the only input. 'Scarcity' of season, however, is an overriding factor and, in interpreting use of labour and returns to labour, due attention has to be paid to the times at which labour can be used. Labour in the busy seasons soon after the rains break, and during the first weedings particularly, has opportunities of being much more productive than labour at other seasons. But farmers' decisions were also constrained by social factors. The villagers gave expression to the kind of pressures which their peoples were experiencing at that time. 'There are many reasons for limiting an area. You may clear a large area which you may not be able to ridge all. Sometimes you lack the seed to cover it all. Sometimes you are overcome by weeds through illness or accidents. All these do happen. Even if you are not sick, continuing rain disturbs your weeding and you find yourself behind time'. Activity on the land before the first rains consisted mainly of slashing and burning regenerated 'bush' and was negligible; during the months of June and July, however, there was an all-out effort among the men to plant and weed the new crop. Farnimg then slackened during the growing season when the rainfall is normally heaviest; in October activity was again accelerated as the groundnut harvest approached, and was maintained until the crop was safely led. Although their efforts on farming were also concentrated largely within the limits of the rainy season, unlike the men, the women maintained a high pitch of activity almost throughout the season. Confined as they were to the heavier rice soils, considerably more work was necessary in pre-planting operations ; the breathing space they might otherwise have had during the growing season was taken up with the additional operation of head-loading rice seedlings for transplanting in the swamp, followed almost immediately by the work of harvesting the early crop of upland rice.

Persistently poor feeding and lowered resistance to disease adversely affected the quality of work of some farmers, and many resorted to the use of 'medicines' and adopted superstitious practices, consulted 'wise men' and purchased expensive *jujus* to 'protect' themselves and their crops."

In describing the nutritional situation in the village during this 'hungry-gap' period which is so widespread throughout Africa, Haswell (1975, p100), continues by quoting one of the Medical Research Council nutritionists, as follows;

"Gamble (1955, pp 108-12) observed in his study of food supplies in Keneba in 1950-51 that during the latter part of the dry season in March-April a number of changes in the types of meals gradually took place. There was a decrease in the amount of rice eaten, gruel, which uses less grain, being served with greater frequency, and even bran - a sign of food shortage - being used in the cooking. In May the mangoes ripen and children begin to eat considerable quantities of the fruit. Towards the end of May one saw the first clear signs of a food shortage. By July products of the 'bush', leaves and fruit, became more frequent ingredients of the meals. In early August one found that there were a number of people who were not getting even one normal meal a day, and were living on boiled leaves and groundnuts...Diarrhoea and various stomach troubles increased noticeably in the village. One found women collapsing by the roadside on the way back from the swamps and having to be helped home, the cause apparently being too much work with too little food...In most compounds local grain supplies were practically exhausted...The latter part of August was perhaps the time of severest hunger. Ten per cent of the people had two meals a day, sixty per cent one meal, and thirty per cent no adequate meal, i.e. no meal with one of the staple grains. The characteristic food of the period was boiled leaves and baobab seed, occasionally with dried *duto* (Cordyla africana ' wild mango' fruit). One sometimes found old men pottering about their farms, up-rooting and chewing the not very ripe groundnuts".

It is interesting that mechanisation trials on previously farmed land showed that the capital and running costs of a tractor were prohibitive in these conditions. Also the crop yields obtained, of 360 kg ha-1 from groundnuts grown using the tractor on brown sandy soils, 158 kg ha-1 from groundnuts grown on grey soils, and 70 kg ha-1 from Digitaria exilis on grey soils, compared unfavourably with those obtained by the local people under their traditional system of hand-hoe agriculture.(Haswell 1975 p 55). It appears that these trials represent a considerably more accurate comparison with the neighouring traditional farming practices than the comparisons so often made between yields obtained, under highly artificial conditions, on experimental farms, with average farm yields, which are usually unreliable anyway.

Another type of mechanisation which had been practised by a few farmers for many years was ox-cultivation. The Mandinka people of Gambia were not traditionally cattle keepers, and the few cattle they owned (no more than a dozen in 1949), had been mainly looked after by itinerant herders such as the Turanko people. Gradually some of the farmers with the larger families began to acquire more cattle, mainly apparently as a form of bank account or insurance. Haswell (1975,p 130) quotes one farmer;

> "I bought these cattle to safeguard my money in case of poor price for groundnuts, and an emergency. I can sell a cow and get some quick attendance without having to go to any trader or moneylender."

By 1962 the number of cattle owned by villagers was over 150 head. The Government Department of Agriculture had started a number of ox-ploughing schools, and twenty schools were operating with 236 pupils. There were some questions whether the widespread trypanosomiasis might cause losses of ploughing oxen. The local Ndama cattle had some tolerance to trypanosomiasis, but the fears that this might break down under the stress of ploughing did not apparently materialise. The number of oxen and ploughs in the village gradually increased, mainly for groundnut growing. Donkeys were also used for groundnut planting and transport. There appear to have been some small increases in yields from ploughing, for example late millet yields increased from 329 kg ha-1 under hand cultivation to 527 kg ha-1 on ploughed land, but the main effect seems to have been to reduce the effort and drudgery of hand cultivation.

There was an actual decrease in the area cultivated per person from 1949 to 1974, but there was a substantial increase in both food crop and total agricultural production (Haswell 1975). The main increase was in groundnut production, which rose from 31.5% of total production im 1949-50 to 46.0% in 1973-74. In the same period the food production rose from 165 to 262 Kg paddy equivalent per person per year (Since rice was the main staple food, other foods were converted into paddy equivalents). This increase was mainly due to larger in swamp rice production. On the other hand there were no increases in millet, sorghum, or Digitaria, which only contributed 3.8% of total production in 1974. Haswell continues;

> "Bush farms above the scarp were found to produce total crop failures after 4 - 5 years cropping under late millet, and required a long period of bush regeneration before they were considered worth bringing under the hoe again".

Haswell draws attention to the wide variations in total agricultural production per person per year between the different compounds in the village. In 1961-62 one compound with 8 members produced a total of 641 kg paddy equivalent per person, of which 27.1% was groundnuts. The poorest compound (No.31), with 15 members, produced only 140 kg paddy equivalent per person, of which 62.8% was groundnuts and only 52 kg was food crops, well below the minimum subsistence level of about 200 kg per person per year. She adds;

> "Neither did compound 31 have sufficient men in the work force to cultivate the 1.5 hectares of groundnuts planted, so labour was hired to assist with the 'groundnut farm', money being borrowed from a trader in Kaiaf to meet this expense; still the combined harvests of rice and groundnuts far from met the requirements of the household in that year even at the barest physiological minimum, and with no alternative employment opportunities open to them, this family became indebted simply to buy the daily bread. Poverty was

more apparent in 31 than in any of the other sample compounds; shelter was of mud and thatch and badly in need of repair, and possessions were pathetically few." Haswell (1975, p123).

Overall , however , the figures indicate a slow but steady increase of 2.0% per person ,per year for food crops, and 3.0% for total agricultural production, from 1949 - 1974. One of the more obvious ways in which this increase in prosperity showed itself was in the number of living huts with corrugated iron roofs, which increased from none in 1949 to 84% in 1974 (Haswell 1975, p 177).

6.2. Burkina Faso

Working in the ICRISAT project, Matlon (1984, pp 99 on) gave preliminary results of a limited number of researcher - managed trials or demonstrations of the traditional sorghum or millet intercropped with cowpeas or groundnuts. In one trial on sorghum intercropped with cowpea in Koho village in 1982, with an annual mean rainfall of 950 mm, he found that net returns to the land could be increased by an average of greater than 60% as cowpea density was increased. The yield of cowpeas could be further increased by insecticide treatment, but he found that this treatment was uneconomic under intercropping conditions. Farmers who were invited to comment on the trial responded as follows:

> "Farmers were generally unimpressed with the increasing aggregate production brought about by increased cowpea density. They pointed out that the risk of animal damage was considerably greater at high densities. They also pointed out that labour requirements for weeding would be substantially greater with a high population of the rampant local varieties of cowpea and that the use of animal traction for weeding and ridging would be impossible. Farmers also observed that the substantial reduction of yields for sorghum (in their view, the priority component in this cereal - legume mixture) was unacceptable. In short, they felt that the possibility of higher financial returns from cowpeas grown at high densities did not offset the disadvantages and that the traditional density better met their objectives and was more consistent with their available labour".

"Commenting on the sorghum - groundnut mixture, farmers explained that they considered groundnut the priority crop in the system. They noted that competition for light at high densities of sorghum forced the groundnut plants to grow upward, with reduced rooting and nut formation. They also criticised the spatial arrangement of groundnuts as being too close to allow adequate nut filling. In conclusion, they recommended a planting pattern that would increase the proportion of groundnut in the mixture, give greater room for each groundnut plant, and substantially reduce shading from sorghum.

As a result of the input from farmers, together with the returns analysis, the accent in subsequent on-farm trials of intensified cereal-legume mixtures has been shifted to groundnut-based systems. Planting patterns were modified to reflect the objectives expressed by the farmers, and early maturing varieties of sorghum and millet were sown late in some treatments (an alternative not now available to farmers) in an attempt to increase sorghum densities without adverse effects on the groundnut".

Matlon's experience with these on-farm trials illustrates one of the valuable aspects of on-farm research, which is the possibility of both involving the farmers in trial design and implementation, and getting their views on the results.

6.3. Nigeria

Norman has described the farming systems in several areas of Northern Nigeria. For example he presents the following data on complex and nuclear family units.

Table 9. Characteristics of complex and nuclear family units (economic units), Nigeria (Derived from Norman 1981, table 6.2, p 22, and Table 6.13, p29).

	Zaria		Bauchi	
Mean rainfall (mm/year)	1115		1102	
Population density	medium		low	
Family structure	Complex	Nuclear	Complex	Nuclear
Percentage of families	49.0	51.0	35.6	64.4
Size of family	10.9	6.2	7.5	5.1
Number of male adults	3.0	1.3	2.2	1.2
Farm size (ha)	5.4	2.6	4.5	3.6
Area per resident (ha)	0.5	0.4	0.6	0.7
Area per male adult (ha)	1.8	2.0	2.0	3.0
Dependent male adult ratio	3.6	4.8	3.4	4.3
Age of family head	-	-	48	42
Average number of cattle	4.4	0	1.28	1.00

He discusses the breakdown of the traditional complex family units containing more than one married man plus dependents, into simple nuclear family units with just one married man plus dependents, which is occurring rapidly (Norman 1981, p21). This seems to be a complex process to which many factors of so called "modernisation" may contribute. This is thought to be having substantial effects on farm mechanisation. It appears to be considerably more difficult for the smaller nuclear families to acquire animals and equipment for animal traction, than for the larger complex family units. Although in theory it would seem possible for the smaller families to acquire animals and equipment in proportion to their size, in practice it appears that the larger complex families own more cattle in proportion to the family size and are able to acquire equipment more readily than the smaller families. He continues;

> " In recent years, prices of cash crops have increased relatively less rapidly than those for animals and equipment. This slows down the adoption of animal draft power, and diminishes the beneficial interaction between crop production and livestock management. It also creates the danger of further aggravating the dual economy that is developing between those farmers who have oxen and equipment and those who do not". (Norman 1981, p70)

In an interesting and useful discussion of labour in West African agriculture he suggests that labour, and not land, appears to be the major factor limiting increased agricultural production at the present time. He goes on to point out that labour shortages are seasonal, and may cause severe bottlenecks to increased production at the busiest times of the farming year. For example, he quotes the following data for Zaria and Bauchi.

Table 10. Indicators of seasonality of work, Northern Nigeria
(Derived from Norman 1981, table 6.13, p29)

	Zaria May to Aug	Bauchi June - Sept.
a) Four busiest months. % of annual man-hours on farm.	50	53
b) Peak month	June	July
Man-hours worked on farm	256	210
Days worked per family male adult		
Farm	17	19
Off-farm	7	7
Total	24	26

The data in table 10 show that over 50% of the total labour time on the farm is concentrated in the cropping season from May to August in Zaria or June to Sept in Bauchi, and between a third and a quarter of this time is spent during the peak month (June in Zaria and July in Bauchi). But even during the peak month, male adults worked for an average of 7 days off the farm, and they worked for an average of 5.0 hours a day on the farm in Zaria and 5.3 hours in Bauchi. (An additional half to one hour was spent walking to and from the fields). It is interesting that these farm working-hours agree closely with those recorded by Haswell (1975, p 50) in Gambia, of 5.1 hours for adult males, but adult females averaged 6 hours there.

Norman (1981, p 34) has pointed out that farmers attempt to reduce this labour bottleneck in several ways, which include:

1) Working longer hours during the busy season.

2) Expecting children to help with certain types of farm work.

3) Hiring or otherwise obtaining extra labour. This is often difficult because of cash shortages at bottleneck periods, and because labour may be in short supply when people are busy on their own farms.

4) Growing crops in mixtures, which can help to smother weeds, and planting "cash" crops after food crops are well established

5) Mechanisation. In Nigeria mechanisation mainly consisted of the introduction of ox-ploughs or ridgers which allowed larger areas of land to be cultivated, but were not used for weeding, so they may have actually increased the weeding bottleneck. However, in the francophone countries the rapid spread of light multiculture weeders appears to be a response to this constraint.

6) Herbicides. In general these appear to have made rather slow progress in the region, probably mainly because the economic incentive for their use often seems doubtful, but also because they are difficult to use in mixed crops. They may also tend to reduce soil organic matter. Recently their use seems to have become more widespread on certain crops in some francophone countries, such as on cotton and maize in southern Mali, and on rice in Ivory Coast.

Norman goes on to describe the substantial amount of hired labour which was employed on these farms (Table 11).

Table 11. Source of farm work (From Norman 1981, tables 6.7, p 24 & 6.11, p 26).

Source of Farm Work	Zaria	Bauchi
	(% of total	man-hours)
Family: male adults	72.2	73.3
Female adults	0.3	1.6
Large children	8.9	9.4
	81.4	84.3
Hired: hourly	8.6	6.4
Contract	9.1	4.5
Communal	0.9	5.1
Sub Totals	18.6	16.0
Totals	100.0	100.3
Annual total man-hours on the family farm -	1800	1317
Man-hours worked during the cropping season -	900	658
Annual hours worked per male adult on & off farm-	1166	1159

These data indicate that in northern Nigeria women do less than 2% of the on-farm work. Although Norman ascribes this to the northern Nigerian Moslem practice of keeping women in seclusion, elsewhere in West Africa Moslem women are not kept in seclusion to anything like the same extent, (c.f. Delgado 1978 for Burkina Faso, 1ER 1980 onwards for Mali, Haswell 1975 for Gambia) and they carry out a much larger proportion of the farm work. The fact that nearly 50% of the labour force in northern Nigeria does not do any farm work, even in the busiest bottleneck periods, seems strange in the light of Norman's suggestion that labour is the major limiting factor.

Table 11 indicates that some 16-19% of farm labour in Zaria and Bauchi is non-family labour. Whereas in Bauchi 5.1 % is communal labour, this type of labour has almost disappeared in Zaria. Norman ascribes this decrease in communal or group-organised labour to increased individualisation through increasing contact with the modern world in Zaria.

Discussing land holdings, Norman (1981, p36) emphasises that throughout the West African savanna, in general individuals have only had rights to use the land under the traditional communal tenure systems. Legal ownership is normally held by governments. The right of use usually passed from father to eldest son, or in moslem societies, the land was divided among the sons. Probably because of this system, and also because people using hand hoes were physically unable to cultivate more that 1-2 ha per worker, few large-scale inequalities in land ownership and use developed in West Africa. However,there are signs that this relatively equitable distribution may be changing in some countries, where powerful groups are attempting to gain control of large tracts of land.

The introduction of ox-powered,and particularly, tractor-powered, mechanisation may lead to attempts by a few individuals to acquire large land holdings. The national economy may benefit from the emergence of a group of larger scale farmers, who can invest capital and increase their farm production more easily than smallholders, particularly where these farmers can acquire land which was previously unused, and farm it well. Unfortunately the land-use practices on some of the large farms which are being cleared and developed in Nigeria with the use of heavy and often inappropriate machinery are so damaging to soil fertility that the soil productivity may be severely harmed within a few years (Lal et al. 1986).

Also in some areas there are increasing signs that a few powerful groups are attempting to gain control of land which has been traditionally cultivated by smallholders, who may either have to pay rent to the new "landlords" or be dispossessed. This trend could cause very severe inequalities and stresses in rural communities.

As population density increases, it appears that traditional communal systems of land tenure tend to break down, and initially the right of land use and eventually, the land itself is bought and sold as it is in most parts of the world.

6.4. Uganda

Carr (1982) has described the agricultural trends from 1910 to 1970 in the three districts of Acholi, Lango, and Teso, which lie in the subhumid savanna zone of northern Uganda. The rainfall pattern varies from a bimodal distribution with a total of about 1200 mm in two rainy seasons a year, from March to June and from August to November, in the south of this region, to a unimodal distribution with about 900 mm in the north-east, with one rainy season from April to October, and a dry season from November to March (Ker et al 1978 p 13).

Carr (1982, p 4) points out that:

> "The people of Acholi, Lango, and Teso areas in north and eastern Uganda have shown themselves both innovative and adaptive in their farming practices over the past sixty years. Their most striking innovations have been the adoption of cotton growing on a very large scale, and the use of ox ploughs for land preparation. There have been, however, a number of other changes which indicate the flexibility of their approach to farming. These can best be indicated by describing the farming systems of three tribal groups at four points in their development, 1910, 1923, 1938 and 1969.
>
> There are not a lot of quantitative data available for the earliest date but there are descriptions of the crops grown and the farming systems used. Cotton had just reached Teso and Lango by 1910 but was still unknown in Acholi. The first ox ploughs had been tried in Teso but had as yet had no impact at all on the mass of farmers and were unknown in Lango and Acholi. Land was normally opened to finger millet which was the dominant crop in all three areas. In Lango and Acholi this was interplanted with pigeon pea. In Teso groundnuts were common, but they had not yet become established in Lango and Acholi where sesame and cowpeas were the main subsidiary crops. Some sorghum was grown but maize was virtually unknown throughout the area as were cassava and sweet potatoes. The last were moving into Lango at this time and were so

highly valued that one bundle of cuttings was accepted as a dowry (equivalent to four cows)".

Although published data on crop acreages were of doubtful reliability, they indicated clearly that between 1923 and 1969 farmers introduced four quite new foodcrops, groundnuts, maize, sweet potatoes and cassava, and a completely new "cash" crop, cotton, into their farming system, and in some areas introduced ox-ploughing. (Anthony et al. 1979, p 140, point out that Teso District was one of the first areas in tropical Africa to adopt the ox-plough, starting from 1910). The traditional staple food crop in this area was finger millet (Eleusine coracana), which was normally planted on land newly cleared from bush and often mixed with legumes such as pigeon pea. This would be followed in the second rains by sorghum and sesame. This pattern would be repeated in the second year, and then the land would usually be allowed to rest for about seven years.

After the introduction of cotton, farmers soon found that it grew well on newly opened land, and if they kept it clean-weeded it provided a very suitable seedbed for finger millet, so cotton became the first crop in the rotation, followed by finger millet, which might be followed by a second cotton crop, or by sorghum or sweet potatoes. Later cassava came in, usually replacing sorghum as the last crop in the rotation before the resting period, and it has become increasingly important in recent years. A few farmers planted groundnuts as the first crop, followed by cotton or sorghum in the second rains, or groundnuts were sometimes intercropped with cassava (fig 13).

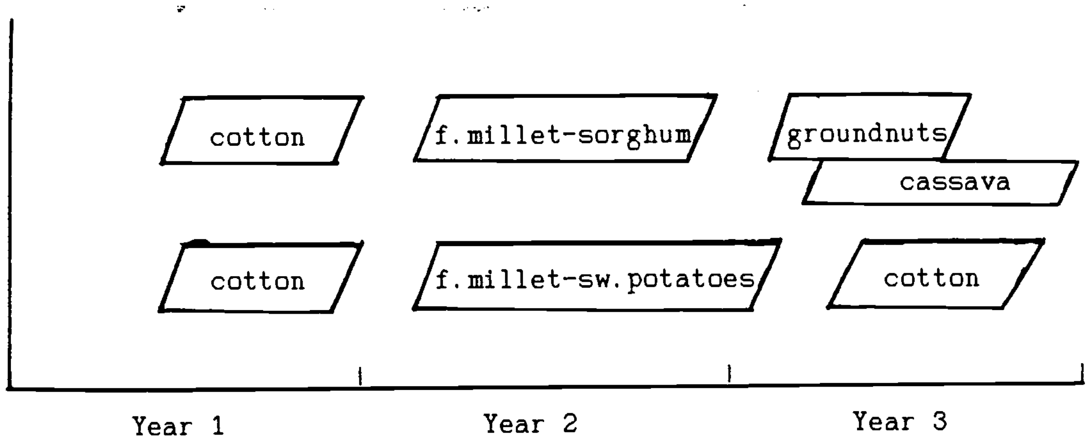


Fig 13. Cropping patterns in northern and eastern Uganda (Derived from Carr, 1982, p5)

Carr (1982, p 7), points out that the Nilotic peoples of Acholi and Lango, where ample fertile land was available, traditionally cleared and hoed new land for each farmer, in groups in exchange for beer.

In Teso the number of ox ploughs increased from 282 in 1923 to 16,000 in 1938, when it was estimated that 90% of the new land was being opened by plough, and to an estimated 70,000 in 1969. Lango and Acholi were slower to adopt the plough, probably partly because the tsetse fly limited the number of cattle in part of the area, but the number of ploughs in Lango increased from 35 in 1923 to 17,000 in 1969 (Acholi numbers are not available). Large numbers of livestock were kept, as shown in table 12.

Table 12. People and Livestock numbers in Acholi, Lango and Teso Districts in 1963. (Uganda Census of Agriculture, 1963)

District	Population Total	Cattle Total	Cattle Per Holder	Sheep Total	Sheep Per Holder	Goats Total	Goats Per Holder
Acholi	340,444	135,000	2.66	63,000	1.24	116,000	2.29
Lango	402,532	371,000	5.24	96,000	1.35	219,000	3.09
Teso	551,972	660,000	6.57	48,000	1.48	222,000	2.21

Although accurate data are difficult to obtain, it is clear that cotton production increased rapidly in all three districts, from nothing in 1910 to nearly 100,000 tonnes in 1938, and to about 120,000 tonnes by 1970. Although the total areas under crops per person were difficult to determine accurately, they were estimated at 0.8 ha in 1963. This figuere includes double cropping the same field, so the actual area cultivated was about 0.6 ha per person, since not all fields were double cropped. Such data as are available suggest that before the introduction of cotton and ox ploughs about 0.4 ha per person was cultivated, so it is clear that farmers expanded their cultivated area per person considerably, mainly by growing cotton as an additional crop, and the introduction of ox ploughs assisted in this expansion. But Parsons (1970, p134) points out that the Acholi and Lango farmers did expand their cultivated area per person in order to grow cotton, even before the introduction of ox ploughs.

The division of labour between the sexes has also changed, as in 1910 the Langi men carried out all the work of preparing land and sowing food crops, while the women did all the weeding, and harvesting was shared between them. With the introduction of cotton, men still do most of the land preparation including ploughing and planting both cotton and food crops, also weeding and harvesting cotton. The women do some of the land preparation and planting for food crops, all the weeding of food crops and share the harvesting. Men are still responsible for herding cattle.

The agricultural extension service made considerable efforts to introduce other types of ox-drawn machinery in addition to ploughs to farmers over the years. These included weeders, seeders, and various toolbars, including the Ariana and the wheeled tool carriers named the polyculteur and tropiculteur, but none of this equipment was adopted by more than a few farmers, despite prices which were sometimes heavily subsidized (Starkey 1987).

Tractors were also purchased by a few farmers, mainly in Acholi, and a government tractor hire service was established. From 1962 onwards this was greatly expanded and tractor-cultivated group farms were also established. By 1966 a maximum area of nearly 14,000 ha was cultivated by the tractor hire service and on group farms in the three districts, after which the area cultivated steadily declined despite heavy subsidies. Carr (1982, p46) concluded;

"The tractor hire service has been a considerable burden on the tax payer (the losses on running costs absorbed the basic graduated tax of 161,000 heads of households in 1967). At the same time it has not appreciably increased output from those who have benefited from the service. The main reason for this is that it has only intervened at one point in the farming year, namely primary cultivation. It has not relieved any other labour bottlenecks so the overall acreage that a family can handle has not been materially changed........As weeding, picking and sorting absorb over 80% of the total labour input for the crop, and as the tractor hire service makes no contribution to these activities it would not appear to be meeting a critical need in the farming pattern. What it does appear to have dome is to transfer resources from the poorer members of the community to those who are more wealthy".

Carr's overall conclusions from this study appear to have considerable significance for the future of agriculture, not only in Uganda, but throughout Africa. He points out that the most rapid expansion of cotton growing in north-east Uganda took place in the 1920's as a result of:-

1) The establishment of law and order and a stable administration which decided to develop the country through the encouragement of peasant farms.

2) The building of the Uganda railway in 1907 and its gradual extension, reaching Lira in 1929, together with a network of feeder roads which permitted low-cost transport of the cotton crop.

3) The encouragement of private traders to buy, process and export cotton at prices which provided adequate incentives to the growers to produce the crop.

4) The availability of a cotton variety well adapted to local conditions and to simple management.

5) The farmers' willingness to fit an additional crop into their farming system, mainly by planting it after weeding their priority food crops, so that its labour requirements fitted into their pattern of labour availability, in a situation where land shortage was not a constraint. (The introduction and adoption of ox-ploughs, particularly in Teso District, undoubtedly assisted farmers by reducing the labour requirement for opening land, therebye enabling them almost to double their areas under cultivation. Farmers using hand hoes also adopted cotton growing but were only able to increase their cultivated areas by about 50%)

6)The ready availability of simple consumer goods, and the need to pay taxes in cash.

As a result of the above, cotton production from eastern and northern Uganda increased from very little in 1910 to an average of about 90,000t in 1934-39, making a considerable contribution to the country's foreign exchange,and therefore to its overall prosperity, as well as to farmers'incomes.

Although it is difficult to obtain facts to confirm or deny this hypothesis, it is my understanding that farmers also grew cotton because the cash income which it provided not only enabled them to purchase their simple requirements and to pay taxes and school fees, but because it provided some insurance against the inevitable food crop failures due to drought or other causes, which they experienced regularly. Sometimes their surplus cash would be used to purchase cattle or other livestock, mainly as a 'bank on the hoof' to be sold and the proceeds would be used to buy food when necessary, or it might be stored in a hole in the ground, or, more recently, in a cooperative savings account.

It seems likely that at least part of the reason for the severe impact of the 1983-84 drought in northern Uganda was the decline in cotton production due to marketing and other problems, so that production reached a low level of about 15,000 tonnes from the three districts by 1980. Although farmers attempted to respond by increasing their production of cassava, some of which was sold, this does not seem to have compensated for the non-availability of the cash income from cotton for buying food. At the same time there were indications of declining yields throughout the area, and particularly in the heavily populated parts of south Teso., caused by declining soil fertility.

On cotton marketing, processing and pricing, Carr comments as follows (p70):

> "The ginners were..... favoured through "cost plus" pricing mechanisms which encouraged inefficiency, cut down competition and reduced the price to growers. At a later date government has protected and subsidised co-operative activities and eliminated any competitive element which might have provided improved services or prices to farmers. It has further given sole responsibility for marketing and latterly for price determination to the Lint Marketing Board as a means of protecting government's own interests and control over the industry at the expense of efficiency and cost effectiveness".

Analysing the north-east Uganda experience in terms of its implications for future development, both in Uganda and elsewhere in Africa, Carr (1982, p 72) points out

"There are two striking facts which come out of a study of the experience of the annual cropping zone of Uganda for the period that has been reviewed. The first is the rapid positive impact on the productivity of small farmers of a stable political situation combined with good infrastructure which encouraged efficient marketing and competitive pricing. The second is the underestimation by government over many years of the farmers' sensitivity of response to real price incentives. As a result of its apparent lack of understanding of the underlying forces which motivate farmers, successive governments took initiatives which reduced both the quality of marketing and the level of economic incentives to farmers. This was basically a result of the government's dichotomy of policy in which claims were made that it was concerned to encourage and protect farmers, whilst in fact its main objective was to protect other interests, increase its own revenue and engender foreign exchange earnings which were largely used by the non-peasant farming sector of the community.

Because of this basic dichotomy, government for many years attempted to replace price and market incentives by increased agricultural services as a means of stimulating production. This often had the effect of presenting farmers with two conflicting signals. On the one hand the extension staff were pressing farmers to increase their labour input into the cotton crop through earlier planting (involving increased weeding) and higher plant populations, whilst the pricing policy was decreasing real returns per labour unit for cotton production. This remains a common feature of governments in Sub-Saharan Africa today. Political exhortation or extension pressure is applied to farmers to produce one crop whilst pricing signals encourage them to produce another. Alternatively campaigns are mounted to encourage the use of purchased inputs whilst pricing policies are reducing the benefit to cost ratio of the proposed innovation.

Whilst the experience in north and east Uganda in the middle years of this century makes it quite clear that agricultural services are not an alternative to price incentives and cannot function effectively in the face of contradictory economic signals, this does not mean that there is no potential role for such services.......

A......factor which has militated against the production of research results leading to viable technical packages for rain-fed farming in the savanna belt in particular, has been the pressure on research workers to embark on lines of study which will result in the publication of papers of sufficient scientific merit to further their professional careers.

The field level adaptive trials and the work on simple innovations to relieve labour bottlenecks, which are a necessary part of an effective programme to produce viable recommendations for small farmers in many areas, carry less academic prestige and in consequence are unattractive to people concerned with their professional advancement and reputation in the scientific world. Without a change of emphasis which gives acclaim to work on the basis of its utility rather than solely on the level of its complexity, it will be difficult to obtain the services of the best workers to deal with many of the actual problems faced by small farmers".

Uchendu and Anthony carried out a detailed study of some 45 farms in Teso District in the mid 1960's. Table 13 summarises some of this data.

Table 13. Farm data, Teso District, Uganda, 1966 (Uchendu and Anthony 1975, p132).

	Southwestern Teso Serere/Soroti	Southeastern Teso Ngora
Number of farmers in sample	21	24
Persons per farm	10.2	6.2
Farm size [ha]	7.3	2.6
Largest farm [ha]	20	5.7
Smallest farm [ha]	1.6	1.0
Number of blocks per farm	1.1	1.3
Area under cotton [ha]	1.9	0.7
Area under all crops [ha]	5.6	2.5
Percent of holding cropped	77	94
Area cropped per person [ha]	0.6	0.4
Cash inputs (shillings)[1]	218	55
(of which labor)	(149)	(23)
	Cash returns (shillings)[1]	
Cotton	1,166	295
Groundnuts		8
Cattle	69	100
Other crops	20	13
Gross returns	1,255	416
Net returns	1,037	361

[Note 1. The approximate exchange rate at that time was Uganda shs 8 = US$ 1.0].

Anthony et al (1979, p131) commented on this study as follows:

" Ngora, Kumi and Bukedea Counties had population densities of 93, 68, and 64 people per square kilometre respectively in 1965. Pressure of human and livestock numbers had become critical in Ngora County. Some voluntary migration had taken place within and beyond the district to relieve pressure on the land, but by 1966 had virtually stopped. Migration is a traditional method of adjusting growing populations to available resources, but provides no satisfactory answer once land is in short supply".

Samples of progressive farmers interviewed by Uchendu and Anthony were found to have cropped 44 and 57 percent of their holdings in Serere and Soroti counties in southwestern Teso District and Ngora County in southeastern Teso District in 1966. The corresponding sample of neighbors of the selected progressive farmers in Serere and Soroti counties cropped an average of 77 per cent of their holdings. Continuous cropping had become the pattern in Ngora, and land could no longer be rested between crops. Grass filter strips were increasingly encroached upon, and some farmers cropped the whole of their cultivable land. In other parts of southern Teso, land was cropped for two or three years and fallowed for two. In northern Teso, it was still possible to fallow for three or four years.

Land hunger in Ngora had created a market for land, and nine of the twenty-four farmers interviewed in the county had rented land for cash payments. Farms were becoming fragmented. They were desperately small, and the area devoted to cash crops and the gross farm income correspondingly low. The net return per farm for the sample farmers in Ngora was only a third of that of the sample in Serere and Soroti counties.

Ker (1966) described the agricultural practices in Bukedi District, Uganda, which lies immediately south of Teso District, and has a similar climate, but being nearer the equator the two rainy seasons are distributed more evenly throughout the year, particularly in the south. The Iteso people in the northern Pallisa county practise the same farming system as their cousins in Teso, whereas further south in the district the systems, though varied, rely increasingly on bananas, maize, cassava, and sweet potatoes to supplement the staple finger millet crop. Cotton is important throughout the district, with a little robusta coffee in the south.

6.5. Kenya.

Although the interactions of altitude, and therefore temperature and evapotranspiration, with rainfall are complex in the highlands, parts of Kenya receive between 900-1200 mm per year of rain and can be classified as sub-humid, though like southern Uganda, the rains in the southern area fall in two rainy seasons rather than one.

For example, part of the lake-shore savanna in Nyanza district has a rainfall of 750 - 1250 mm in two rainy seasons totalling about 120 - 150 days. de Wilde (1967, p122) indicates that part of this area has deep alluvial 'mbuga' soils [mainly vertisols], which, although more fertile than other soils in the district, are difficult to drain and to work.

Population pressure in this area was already high in 1960/61, with about 143 people per km2. It was found that an average of 1.32 ha was cultivated per holding, but 31.5% of the holdings averaged less than 1 ha in area, and 58.7% averaged less than 2 ha. 62% of the holdings were fragmented, with an average of 2.84 parcels per holding. In the past many Luo men (about 24% in 1962) have found employment outside the district, mainly in other parts of Kenya. This led to a shortage of farm labour, although ox-ploughs are fairly widely used in testse - free areas.

Although little information is given on the farming systems, it appears that maize and sorghum are important staples, with rice in suitable locations. Cotton and sugar cane are also widely grown, and some 6,000t of cotton lint and 4,000t of sugar cane were marketed in 1963.

The two districts of Elgeyo - Marakwet and Baringo lie north of Nakuru partly in and partly on the edge of the Rift Valley. Since much of this area has a rainfall between 1000 - 1250 mm it appears to come, at least partly, into the subhumid zone. However, the large variations in altitude, from 1000 m altitude and about 500 mm rainfall near the Kerio river on the floor of the Rift Valley, up to 3000 m altitude and over 1250 mm rainfall in the Cherangani Hills, lead to a great diversity of agro-ecological conditions in a comparatively small area. These need considerably more detailed analysis than is possible here, and many parts of Kenya have, in fact, been studied in detail. However, the development process which is taking place in this area is of considerable interest and may have implications for similar areas elsewhere, so a brief description, mainly taken from de Wilde (1967, pp 157 - 187) will be included here.

The people of the two districts are mainly of the Kalenjin language group described by de Wilde as nilo-hamitic. In 1965 there were approximately 91,000 Elgeyo, 65,000 Marakwet, 103,000 Tugen, 20,000 Pokot or Suk, and a few Njemps. These numbers can be expected to have approximately doubled by 1987.

Although part of south Baringo is relatively fertile, with an altitude varying between 2000 - 2600 m, and a good rainfall, suitable for permanent agriculture, most of the district lies in the bottom of the Rift Valley at 1000 m altitude or less , with a rainfall of only 500 - 750 mm per year. This part of the district is the scene of severe land degradation resulting from uncontrolled grazing of stock. L.H. Brown of the Kenya Department of Agriculture (de Wilde 1967, p 175) described it as follows:

> "Baringo District has in fact reached an 'overgrazing end point' where most of the grass and the topsoil has already gone over large stretches of the country, and the ground is blanketed with thornbush, largely useless to man and beast alike, which cannot be eradicated without the expenditure of large sums of money...This tragic situation has not been caused by overstocking alone. In Baringo, and in similar situations on the Elgeyo escarpment, and the lower slopes of the Cheranganis in West Pokot, it has also been aggravated, over a long period of time, by shifting cultivation on steep slopes with shallow soil wothout any effective soil conservation measures...........The general overall degree of deterioration ....is more severe than any deterioration of range recorded in, for instance, the USA in similar rainfall".

Over the years many attempts were made to introduce grazing control into this district, but none of them appear to have achieved much success, and the deterioration of the environment continues. It is not intended to cover this pastoral system in detail here, but this represents one side of the picture.

The other side is represented by parts of Elgeyo - Marakwet. This district lies mainly on the highland edge of the Rift Valley, at an altitude of 2000 - 2600 m, but includes the steep escarpment and an area along the Kerio river at the bottom of the escarpment. Traditionally it appears that most of the Elgeyo - Marakwet people used to live on the escarpment, tilling subsistence crops such as millet, sorghum, maize and cassava in a form of shifting cultivation, and keeping livestock, mainly sheep and goats. Few data were available on their activities, as they were relatively inaccessible and neglected by the Department of Agriculture. However, the Marakwet in the north of the District who were particularly isolated, did develop some indigenous systems of irrigation, making use of streams which flow down the escarpment, and a rather intricate set of furrows and aquaducts, to irrigate crops, particularly maize, on the valley floor. Although the irrigated area only amounted to about 1000 ha in 1965, it appeared that there was some potential for expansion to about 4,000 ha.

In contrast, de Wilde (1967, pp 166 - 169) described the Elgeyo farming system as follows

> "While the Elgeyo still clinging to the escarpment are said to be virtually as traditional and conservative as the Marakwet, a much higher proportion of the tribe has moved onto the high plateau couuntry of the Irong and Mosop Locations where they have shown a capacity for rapid change, ...This mobility and change.......impressed us as one of the striking phenomena of Kenya's development in the last two decades. Initially the land in the higher reaches of the Division was used only for communal grazing of stock which could no longer be kept all year on the escarpment. The young men detailed to guard the clan herds by the elders, who themselves remained in the escarpment, gradually began to clear patches in the forest for food crops, primarily maize.

Others who returned from wage employment on European farms or in the district's sawmills joined them in staking out land, particularly as they were unable to find land on the escarpment. Also, as more stock invaded the plateau and competition for grazing began, there was a progressive tendency to enclose grazing land too, first only for dry-deason grazing and then more extensively. Enclosure, which began only in the late 'forties, was virtually completed in all of the highlands by the close of the 'fifties. It took place usually in the face of the strong resistance of clan and kokwet elders who wanted the land reserved for communal grazing and begrudged its use for crops............

In a sense, the Elgeyo who took up farming on the plateau proved almost excessively responsive to new opportunities. Thus when the settlement and purchase of European farms became possible, some 900 to 1,000 Elgeyo farmers abandoned their farms to take up allotments on settlement schemes or to buy, individually or possibly with others, European farms on their own initiative in 1962 and 1963. They had hardly exhausted the production possibilities of their existing farms before they were ready to 'graduate' to new opportunities".

6.6. Tanzania.

A large proportion of Tanzania comes into the sub-humid zone with 900 - 1200 mm annual rainfall which is received in two rainy seasons in northern Tanzania, becoming one further south. For example, de Wilde (1967, pp 415 - 450), has described the agricultural situation in Sukumaland, to the south of Lake Victoria. In 1965 about 1.1m Sukuma occupied an area of about 44,000 square kilometres. They possessed some 3.5m cattle and 3m sheep and goats (These numbers may have doubled by 1987). The soils range from light, free-draining and erodible hillsands to heavy "mbuga" soils (vertisols) in the valley bottoms in a gently rolling topography. Traditionally, the Sukuma practised shifting cultivation of pearl millet and sorghum, but in recent years maize has tended to become the dominant cereal. Cassova, groundnuts, sweet potatoes and legumes are also grown. Cotton is the most important cash crop, and some rice and sisal are also produced, mainly for sale.Ruthenb erg (1980, p 97) quotes data from Pudsey (unpublished) indicating that about 1.25 ha of cotton, 1.25 ha of sorghum, millet and maize (often mixed), 0.60 ha of rice, and 0.70 ha of cassava, giving a total crop area of 3.80 ha were grown on farms averaging 8.5 people on 6.90 ha in 1976. This gives 0.33 ha per person of food crops and 0.68 ha per person of cotton, or a total cropped area per person of just over 1 ha. With a labour force of 3.7 men equivalents (ME) per farm, equivalent to this is 1.86 ha per ME. An average of 2 cattle and 10 sheep and goats were also kept. By this time most people were living in Ujamaa villages, and had to spend an average of 1.5 hours per day walking to and from their cultivated plots. Upland crops are planted on ridges, 50 cm high and 1.3 to 1.5 m apart, made with hand-hoes. At the beginning of each season the weeds and crop residues are removed from these ridges and put into the furrows. The ridges are then split by hand so the organic matter is concentrated in the centre of the ridge and the weeds are smothered. The new season's crops are then planted on the ridges which assist in reducing erosion. Tie-ridging was tried, but is not generally practiced. Ox ploughing has spread rapidly since the 1950's particularly in the drier areas, especially for cotton growing on the flat. This roughly doubled the area cultivated per worker.

With the growth of population, land pressure has increased and it appears that some 70% - 80% of the potentially arable land is cropped each year. Cotton and cereal yields are gradually declining, and the area of cassava is increasing as soil fertility declines. Manure is left in the bomas, and is not normally applied to the fields. Occasionally a boma may be moved and the site may be used for vegetables or other garden crops. This system is very demanding for labour before and during the cropping season, requiring about 2226 man hours per ME, roughly half for cultivation and half for herding. The gross margin per hectare or per worker was about US $187 in 1976.

This system appears very similar to that practised in the comparable agro-ecological conditions in Acholi, Lango and Teso districts in Uganda, described above. (p.......)

The rainfall on the two islands of Ukerewe and Ukara, which lie in Lake Victoria just off Sukumaland, varies from about 1170 -1600 mm, which puts them partly in the sub-humid and partly in the humid zone.

The farming systems practised by the people living on these islands show interesting parallels and differences with those of the Sukuma, so they will be considered here.

Moody (1969) described the system on Ukerewe island. In 1967 the island population was 88,000 on an area of 554 km, giving an average density of 159 km-2. At the then population increase rate of 2.2% per year the density would have doubled to about 320 km-2 by 1987, if no out-migration had taken place. The farming system consisted mainly of cassava and cotton, with about 1.2 ha of cassava and 0.6 ha of cotton per family averaging 9.2 people. Some farmers also grew rice, sweet potatoes, and perhaps a little sorghum, maize or bananas. Some of the fallow land was manured by tethering the 3 or 4 cattle owned by each farmer. Fertilizer trials indicated only a limited response to chemical fertiliser. In general, cassava was cultivated continuously on the hill sands, but was sometimes planted after cotton. Cotton tended to be planted on the hardpan soils.

While population pressure on the land is increasing on Ukerewe, it has been high (500 people Km-2) on Ukara for more than a century (Ruthenberg 1980, p 158). The Wakara have evolved their own intensive land-use system in response to their land shortage. Each family practises intensive cultivation on about 1 ha of land, growing pearl millet intercropped with legumes, applying manure each year in the main rains, followed by groundnuts in the second rains in the second year, and sorghum or cassava after millet in the third year. Also small rice plots are cultivated in the valley bottoms. Manure production is of great importance, and this requires careful production and conservation of fodder. Animals are housed at night and litter is provided for them. The Wakara work harder than neighbouring farmers, but are poorer, with a net income per ME of only US $40 in 1964. If they emigrate to Sukumaland, they usually adopt the local fallow farming system and abandon their own intensive system (Ruthenberg 1980, p 160).

Anthony et al (1979 p 188), have analysed the farming systems practised in Geita district, also a part of Sukumaland, which receives a mean rainfall of about 940 mm per year. They comment as follows:-

"The last thirty years have seen the complete transformation of what is now Geita District from tsetse-fly infested bush and miombo woodland, with a sparse population largely confined to the Lake Victoria littoral, to a major cash-crop and food-producing area. With the removal of tsetse fly and the provision of water supplies for human and livestock needs, immigrants flocked from the crowded areas east of Smith Sound. The population increased about five times from the mid-1930s to the mid 1960s and was settled in individual farmsteads throughout the district. By 1967 Geita was an important cotton producing area and exported substantial quantities of cassava to the central areas of Sukumaland.

In the period before independence, government preoccupation with soil deterioration in central Sukumaland led to emphasis on soil-conservation measures and the promotion of cassava and sweet potato cultivation as famine reserve crops. Farmers abandoned these imposed soil-conservation practices with independence, but they continued to observe the compulsory cotton uprooting date, although imperfectly.

Efforts to secure adoption of soil conservation measures by farmers have thus made little impact, but the other achievements of the colonial period were considerable, not the least of which was the promotion of new crops. The ready acceptance of cotton as a cash crop owes much to the work of the plant breeders at Ukiriguru [research station], who produced varieties with resistance to jassid and bacterial blight. This work, important under any circumstances, has special significance at an early stage of development when the small farmer is least able to bear risks.

The agricultural achievements of Geita District in the 1960s were impressive, and cotton production increased by about 60 percent between 1964 and 1967 largely through increased acreage. Some farmers, however, derived most of their cash income from cassava despite the pressure on them to produce more cotton. The trade in cassava was handled by small merchants who appeared to be more efficient than the cooperative society.

Future increases in cotton production will have to be obtained largely through increases in yields per acre. Individual farmers are already short of suitable land, but there is considerable scope for increasing productivity per acre through early sowing, the use of insecticides and fertilizers, and general observance of the closed season. Adoption of higher yielding practices was limited by an inadequate extension staff and unavailability of modern inputs.

The general acceptance of early sowing has been limited by farm labor bottlenecks. Poor feeder roads make it difficult to open cotton markets before the end of the rains, so that farmers who sow early must store their harvested crop until the market opens.

At present, the economy of Geita District is mainly dependent on cotton production, but with cassava locally important as a source of cash income. Geita in 1967 was ripe for change. The standard of traditional farming was good and Geita farmers constituted a hard-working rural community."

Detailed studies of farm incomes indicated that there were large income differences between so called 'progressive' and neigbouring farmers in the survey area. The 'progressive' farmers obtained both gross and net incomes two and a half times greater than their neigbours, and the differences in production per hectare were nearly as large (Anthony et al, 1979, p 174). They found a strong positive correlation between the efficiency ratings of these 'progressive' farmers and modernization scores that measure social, economic, and technical aspects of farmers' behaviour.

6.7. Synthesis

This zone has the largest potential for cereal production in the savanna. The FAO Agro-ecological Zones Project (1978, p 113), suggests that the regions with growing periods of about 150 to 210 days are most suitable for sorghum, and those with about 150 to 240 days for maize, and these fit well into this zone, with some overlap into the humid zone. In West Africa this corresponds with the northern guinea savanna, which is the principal zone in which maize is spreading actively, mainly replacing sorghum. It appears that this fundamental change in the traditional farming system is occurring for a number of reasons:

1. Small plots of maize have been grown for a considerable time, mainly confined to the relatively fertile areas close to the houses, or sometimes mixed with other cereals.

2. Early maize varieties provide the first food after the 'hungry gap', in the form of fresh cobs.

3. In areas with relatively fertile soils, or where manure is available, farmers have found that maize has a higher yield potential than sorghum.

4. Maize responds well to phosphate and nitrogen fertilizers, particularly where sufficient organic matter is also made available.

5. Development projects often provide a 'package' of maize seed and fertilizer on credit, which has proved popular with farmers.

6. Some governments have attempted to establish attractive minimum prices for maize, which give strong incentives to farmers to produce the crop.

7. Sorghum, millet and rice are particularly susceptible to bird damage, which can destroy the crop if it is not guarded. Early sorghum varieties, when planted early, may mature during the rains and develop grain moulds which reduce quality. Maize is less susceptible to these problems.

8. Many sorghum varieties, particularly the red- or brown-grained bird-resistant types, contain tannins in the seed coat which have to removed during processing. Some varieties of dry maize may be easier to process.

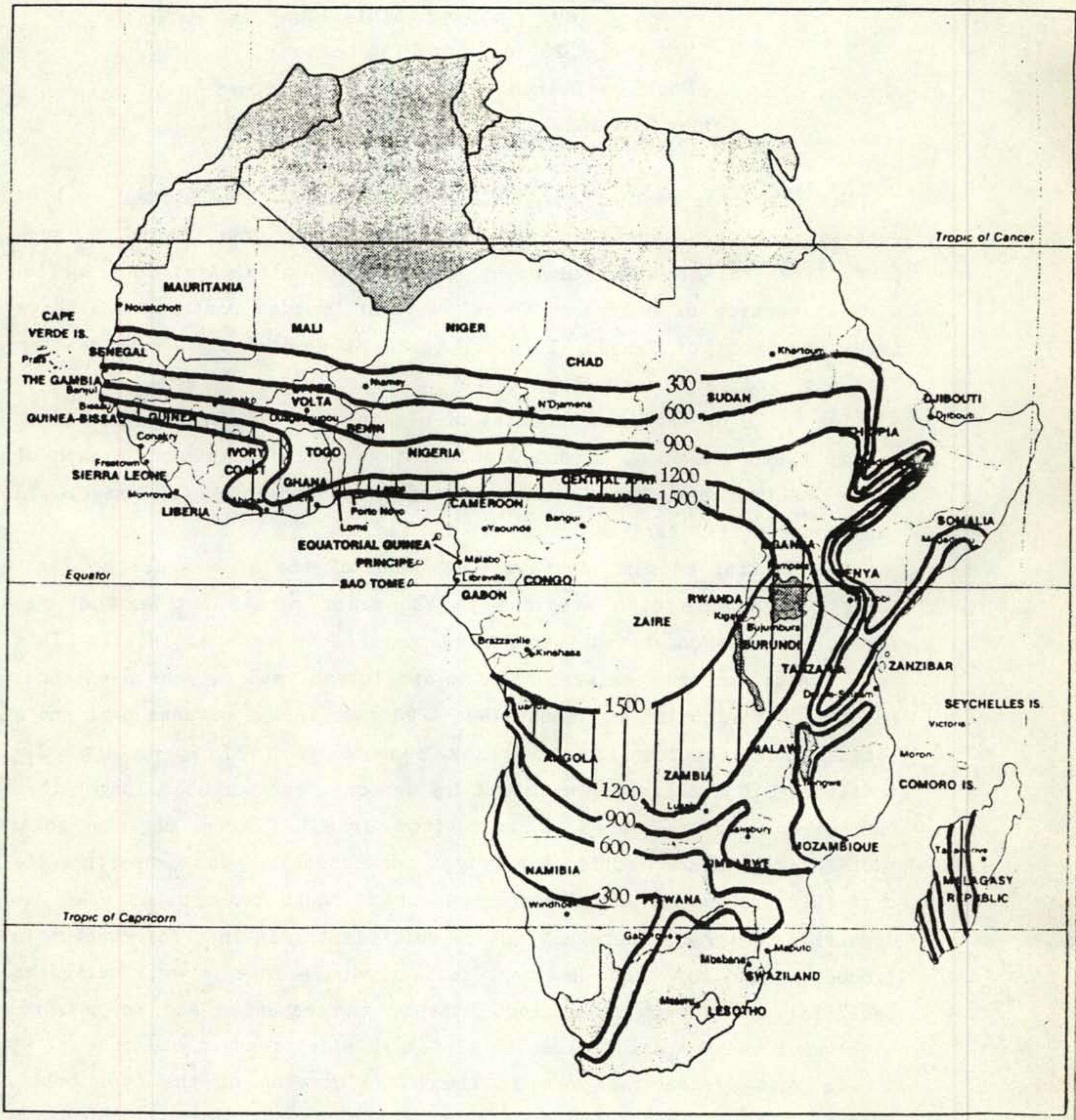
Pearl millet is also grown in this zone, particularly on the lighter soils, and often mixed with sorghum or maize. Rice growing appears to be increasing wherever water is available. Other important crops include cowpeas and groundnuts, often grown mixed with the cereals, and cotton. Sweet potatoes and cassava seem to be spreading into the zone.

Many of the soils in the zone are relatively infertile alfisols, and there are large areas of shallow soils over iron pans or ironstone gravel. Under heavy population pressure soil fertility declines rapidly and severe erosion can take place where bare soils are exposed by over-cropping or over-grazing.

Livestock are important throughout the zone, and it appears that many farmers own an average of about 2-6 head of cattle. In general livestock are grazed on communal grazing land, though they may graze the stubbles, as well as seasonal swampy areas in the dry season. Cattle are widely used for ploughing, and sometimes for carting, in spite of trypanosomiasis problems in some areas. Donkeys and horses are spreading in West Africa for shallow cultivations, planting groundnuts, and carting. A few sheep and/or goats are also often kept.

Certain trees, such as the indigenous shea butternut (Butyrospermum spp.), and the introduced mango, are supplementary sources of food in this zone. Shea butternuts are carefully protected by farmers, but are not usually planted, whereas mangoes are planted.

HUMID SAVANNA ZONE



Chapter 7. HUMID SAVANNA ZONE

1200 - 1500mm rainfall.
190 - 230 days growing season.
Southern Guinea Savanna - West Africa.
Derived Savanna - Eastern and Central Africa.

Starting from West Africa, this zone includes Guinea Bissau, much of Guinea, part of southern Mali, Ivory Coast, Ghana, Togo, Benin, a large part of central Nigeria, Cameroon, most of the Central African Republic, a small section of southwest Sudan, most of Uganda, parts of the Kenya highlands, most of Rwanda, Burundi, parts of western and south eastern Tanzania, and part of southern Zaire.

The soils of this zone consist of ultisols on the West African coast and in Uganda, Rwanda, Burundi, and eastern Zaire, alfisols in much of Ivory Coast, Ghana, Togo, Benin, Nigeria, and Tanzania, and oxisols in Cameroon, Central African Republic, and Zaire.

The natural climax vegetation of most of the zone would be light forest, with some open woodland in the drier parts, but most of the forest has been converted into derived savanna by man's activities. This is a transition zone between savanna and forest, and between a unimodal rainfall distribution in about 190 - 200 days in the savanna part and a bimodal distribution in two rainy seasons each of 2 - 4 months, totalling 210 - 230 days, with two dry seasons, one normally longer than the other, in the area derived from forest. Parts of the zone, particularly where soils are light or shallow, can sometimes be difficult for annual crop production, as although two crops a year can sometimes be grown, there may not be sufficient rain in either season to produce an optimum crop. However, in general the zone is well suited to perennial crops such as coffee, citrus, and bananas, and to pasture. although livestock are limited as tsetse is widespread in the zone.

In West Africa the zone is the main location of the 'yam belt'. This is the area extending from Ivory coast through Ghana, Togo, Benin into Nigeria and part of Cameroon, where yams have long been a traditional staple food.

7.1. Ivory Coast

de Wilde (1967, p 396) has described the yam-growing practices in the region of Bouake´, Ivory Coast.

> "Yams are the most characteristic and basic food crop of the Baoule´ people. It is the crop that requires most of the farmers' time, occupies over half the cultivated land and is the starting point for rotations and mixed cropping. The Baoule´s have acquired a highly developed technique for its cultivation. Proper selection of variety (early or late) and appropriate planting densities (9,000 plants per hectare) enable them to secure very high yields estimated at more than 10 tons per hectare".

Yams are usually planted as the first crop in the rotation, after about six years fallow. They are planted on mounds and are nearly always grown mixed with maize, cassava and cotton. Rice is also widely grown in Ivory Coast, both as an upland and as a swamp crop. A wide variety of other crops, including plantains (starchy bananas), cocoyams, groundnuts, okra, cucurbits, peppers etc, are also grown. Cotton production has increased in recent years, but robusta coffee is the principal 'cash' crop, particularly in the areas derived from forest. The average area under cultivation for a family of 6-7 people with 3 ME's ranged from about 1.15-2 ha or more including about 0.8 ha yams, 0.36 ha rice and 0.8 ha coffee.

One of the characteristics of the Ivory Coast is the large influx of migrant labour, mainly from Burkina Faso, but also from Mali, who work on the coffee and other farms often on a seasonal basis. In 1963 farmers paid out an average of some CFA 1300 for paid labour.

The programme of 'animation rurale' which was developed during the 60's in the Ivory Coast deserves a mention here. This programme was the responsibility of the Compagnie Internationale de Developpement Rurale (CIDR), one of the French societies which play an important role in nearly all francophone countries. The animateurs ruraux were farmers who were chosen from the villages and given short periods of training every month at centres de formation d'animateurs ruraux (CFAR) to return to their villages and work with farmers, doing simple unpaid applied research and extension. This programme appeared to achieve considerable success, but like many such programmes, its success appears to have led to its downfall, as the economic and political consciousness which was aroused was considered a threat.

7.2. Mali

de Wilde (1967, pp 301 - 336) provides an interesting description of the spread of cotton cultivation in Mali. Cotton growing was first encouraged by the CFDT, now the Compagnie Malienne pour le developpement des fibres textiles (CMDT) in the Koutiala region east of Bamako. The Mali government has since made it responsible for all the agricultural extension work in the Mali Sud region under the Ministry of Rural Development. From the beginning a strong emphasis was placed on the use of manure for cotton growing, and farmers were provided with free oxen and equipment on loan for 2 years, provided that they applied about 10-15 t/ha manure on their cotton land. These large quantities of manure appear to have been too much for most farmers to produce and transport to the fields, so this programme does not seem to have continued for more than a few years. Artificial fertilizer was also recommended, as the combination of manure and fertilizer was found to be particularly effective in increasing yields. In 1962 50 kg of ammonium sulphate and 75 kg of triple superphosphate was recommended, at a cost of about VS $18. In 1963 the cost was subsidized to US $12, which led to a large increase in its use.

Following a consultancy mission by Norman and others (lER 1977), the Mali Government decided to start an enlarged programme of farming systems research (FSR) in southern Mali. Part of this programme began in three villages near Sikasso, with support from the Government of the Netherlands, and has been reported by the IER (1979 onwards) and by Kleene (1984, p 131 - 138).

Another section of the programme, which will be described here, concentrated on Gladie, Monzondougou and Sakoro villages which are situated near the Sikasso - Bougouni road, and was also reported by the IER (1979 on). Gladie village was selected because it represented a relatively advanced farming system with many households using animal traction (mainly ox-cultivation), farm-yard manure, and fertilizers, and a considerable production of maize and cotton. Monzondougou represented an intermediate system, with some animal traction and cotton growing but little use of manure or fertilizers, and continued bush-fallowing of the outermost fields. Sakoro represented a more traditional system with little or no animal traction, use of manure or fertilizers, or cotton.

Although the soils in all three villages appeared to be similar fine sandy loams of the alfisol group, shallow in places over plinthite or ironstone gravel, Sakoro had more severe soil fertility problems than the other villages. (IER 1980). The mean animal rainfall recorded at the nearest meteorological stations was around 1,250 mm for all three villages.

An initial survey indicated that the criterion of ownership of animal traction equipment correlated reasonably closely with the surplus production over subsistence achieved by each household. Also although Gladie village had the most households owning animal traction equipment, and these were usually the larger households, there was a considerable range of households from the wealthiest with equipment to the poorest with none. The same situation was found at Monzondougou, whereas at Sakoro although there was little use of animal traction there was still some variation between households, particularly in the size of the households and the number of cattle owned.

At Sakoro it was found that apart from the usual "champs de cas", around the houses, where maize was grown using the accumulated fertility from dung and refuse, the upland soils within about 6 km of the village had not been cropped for many years. The principal crops of sorghum and millet, with cowpeas intercropped at wide spacing, were grown after bush fallowing, in the zone from about 6 - 8 km from the village, together with some small plots of groundnuts, Bambarra groundnuts (Voandzeia sp.), and fonio (Digitaria exilis). The women also cultivated rice in the seasonal swamps near the village. They had the right to sell this rice as their main source of money. The yields of sorghum and millet were found to be about 350 kg ha-1. The survey had also indicated that 80% of the households were below self-sufficiency in food production.

Following the usual farming systems research methodology (see for example, Zandstra et al.), several field experiments were designed in conjunction with the farmers, and carried out by the farmers themselves. These included the local maize variety which was grown as a field crop for the first time on the unused land near the village, with various combinations of farmyard manure and fertilizer. It was found that the crop virtually failed without manure or fertilizer, and even with either manure or fertilizer yields were poor. But on these soils a combination of a small application of 2 - 3 tons/ha of manure (which was available in the village, but had not been used previously), with the recommended rate of 200 kg/ha of compound fertilizer and 100 kg/ha urea top-dressed, gave yields of over 4 t ha-1 of dry grain on some farms.

The extension staff of the CMDT were fully involved in the research at all stages. The CMDT had introduced a scheme for providing maize seed and fertilizer on credit, together with advice to farmers, and they undertook to buy back the maize crop at the Government minimum price which was fixed at 80 cfa kg-1 (about US$ 0.30).

A number of farmers also started using animal traction. Each year an increased number of Sakoro farmers took advantage of this scheme, and by 1985 over 20 ha of maize were being grown. The first effect was to provide a food surplus for those households which grew maize successfully, and several householders sold some of their surplus maize. Before they became self-sufficient in food, Sakoro farmers had never been willing to grow cotton, but once they achieved food self-suffiency, some farmers started growing cotton and groundnuts in rotation with the maize. The residual effects of the manure and fertilizers benefited these crops, and satisfactory yields were obtained.

In 1985 the CMDT extension workers and the IER farming systems research team together decided to extend the testing of some of the technologies which had been adopted by the Sakoro farmers, into four additional villages in the Bougouni zone. A diagnostic survey had indicated that these villages probably had similar problems and conditions to Sakoro, so technologies which were successful in Sakoro should have a good chance of being successful in these new villages. Although it is still too early to assess the results, present indications are that farmers in these villages are enthusiastically adopting the maize-manure-fertilizer package after doing simple trials on their own farms. This work is organized and carried out by the CMDT extension workers responsible for the villages, with some advice and monitoring by the FSR team. If this pre-extension stage proves successful it is proposed to train additional extension workers to organise pre-extension tests in other villages.

In Gladie village, on the other hand, it was found that a group of about 9 households had already developed a highly productive farming system well adapted to their own needs and conditions. This system was based on a rotation with cotton followed by maize intercropped with millet, which could be followed by sorghum or groundnuts, then back to cotton. The cotton and maize/millet received farmyard manure and fertilizer, and animal traction was used for ploughing, and carting manure. Crop residues in the form of maize, millet, and sorghum stalks were carted to the cattle bomas on higher land for manure production during the cropping season, and temporary bomas were made in the cropped area so cattle would produce manure there in the dry season. The women grew rice in the swamps. Crop yields were high, averaging about 2.5 t ha-1 seed cotton, 3.5 t ha-1 maize and 1.5 t ha-1 millet and 1 t ha-1 sorghum in a good year. Gross margin analysis at current input and output prices indicated that this system was highly profitable. These households had a considerable surplus of cereal production over current needs, some of which was sold together with the cotton, and much of the profit appeared to be invested in cattle, of which several householders owned large herds. In general it was found that the larger households were able to acquire animal traction equipment, which seemed to be the key to the success of this system.

At the other extreme, there were some small households in this village, with perhaps a man or woman with young children, or an older person alone. These households could not afford the plough and two oxen needed to expand their area under cultivation, and were therefore stuck in the vicious circle of poverty and intermittent hunger often accompanied by sickness, so common throughout Africa. One farmer even resorted to cultivating a steep and rocky hillside, despite miserably low crop yields and severe erosion, apparently simply because fewer weeds grew on these rocky slopes, so his labour for weeding was reduced.

Because the farming system practised by some farmers in this village was more advanced than in Sakoro, it proved more difficult for FSR to make much contribution to productivity. Shortage of good quality forage in the dry season was identified as a limiting constraint, and forage cowpeas in pure stand appeared to be one approach which was popular with some farmers. Upland rice was another technology which was adopted by some farmers, despite the risks of dry spells during the growing season.

It appears that there are a large number of lessons to be learned from this type of research, among which are the following:-

1) The initial research at Sakoro took about 3 years to test a wide range of possible technologies and to screen out those which could reduce the limiting constraints and were acceptable to the farmers. An additional 2 years were needed to check the results. While this initial long period was partly due to the inexperience of the FSR team, it is essential to take sufficient time to establish a good working relationship with the villagers, and to understand their problems, constraints, and perceptions, if success is to be attained.

2) The FSR team leader can be an agronomist, or an agricultural economist, but whichever he is he needs to have some working knowledge of the other discipline, ability to lead a multidisciplinary team, and an insight into the constraints and potentials of smallholder farming.

3) Despite the best efforts of an experienced team, it may be difficult to identify improved technologies which are sufficiently profitable to be acceptable to farmers in some villages, for reasons which are often difficult to determine. Monzondougou was an example of one of these villages. Although it may be interesting to continue working in this village in the hope of finding acceptable technologies in future it may be more cost-effective to seek more responsive villages.

4) Although FSR can be an expensive exercise, particularly when supported by donor agencies, if it is to be made a part of a resource - poor country's indigenous research programme, it obviously needs to be conducted at a low cost (McIntire, 1984) This appears to be possible provided that researchers with an adequate level of training and motivation are available and willing to work in a group of villages, with perhaps a bicycle or low-cost motorcycle for transport, and

assistants can be recruited from the villages at local wage rates. These teams, consisting at least of an agronomist and agricultural economist, need back-up from animal, soil, and crop protection scientists, or others as appropriate, as well as administrative support.

5) An all-important aspect of FSR is the link with extension. It seems doubtful if FSR should be undertaken unless an effective extension service is willing to be fully involved right from the beginning, in selecting areas for research, carrying out diagnostic surveys, identifying villages and farmers for detailed work, co-operating in on-farm trials, and eventually testing promising results by pre-extension trials in additional villages.

6) Linkages also need to be firmly established with researchers working on research stations, who may conduct part of their own research in FSR villages. Their research programmes should also be modified according to the results and needs of FSR.

7) Although due caution is required in making the results of FSR known to policy makers, once proven research results become available linkages with policy makers should be developed. A tactful way of doing this could be by holding a workshop for policy makers at which a number of fully documented options are presented.

7.3. Nigeria

Farming systems researchers from the International Institute of Tropical Agriculture (IITA) based at Ibadan, Nigeria have conducted on-farm research at a number of locations in the humid savanna zone.

7.4. Uganda

Richards et al. (1973) have described the development of commercial coffee farming in Buganda in the 50's and 60's. Buganda was the largest and wealthiest province in Uganda, with about one quarter of the population of the country. It is situated mainly in the 'fertile crescent', which is the area around the northern and western shores of Lake Victoria which receives a well-distributed rainfall of about 1250-1500mm in two rainy seasons, and much of which has relatively deep and fertile soils (mainly ultisols). The staple food of the Baganda is *matoke*, made from steamed bananas, which grow well in this area. Other important food crops include sweet potatoes, cassava, and Phaseolus beans. Some cattle are kept, but are often herded by employed herdsmen. An interesting recent development has been the spread of modern dairy farms. Goats are also common.

Stimulated by high prices, which rose from 6 cents per pound of dry cherry [about US$ 0.4 kg-1] in 1938, to 100 cents [US$0.33 kg-1] in 1954. the Baganda farmers increased their plantings of robusta coffee from about 24,000 ha in 1944 to over 120,000 ha in 1956, and over 280,000 ha by 1966 (Richards et al. 1973, p 31), making Uganda the world's fourth or fifth largest coffee producing country at that time.

Because Buganda had had an individual system of land tenure for much of the land since the early years of the century, some farmers were able to inherit or buy large areas of land. For example one farmer was found to own nearly 2000 ha of land, and he was still hoping to buy more. However, although land areas actually farmed varied widely, it was found that on average all farms had 0.46 ha of food crops per resident, and this figure did not vary much (from 0.1 to 1.4 ha). The average area under cultivation per farm was 1.5 ha, and the average holding size in Buganda in 1963 was 2.6 ha, with 4.4 people per family. Areas planted with coffee were usually less than 4 ha per farm, but a few farmers had up to 40 ha or more. Average yields of wet coffee cherry on 30 surveyed farms were 2900 kg ha-1, but there were very wide variations in yields from about 300 to over 7000 kg ha-1. The profit margins per hectare and per farm varied in proportion.

Much of the work on the Buganda coffee plantations was done by immigrant labour which came from Rwanda, Burundi, Kenya, Tanzania, and the poorer parts of Uganda to find work. In 1963 over 138,000 were employed on coffee weeding and nearly 58,000 on coffee picking. For a long time the rate of pay was shs 1.00 [about US$0.14] for a one day 'task', which was equivalent to weeding about 220 m2. Many of these 'porters' eventually acquired a plot of land and settled permanently (Richards et al. 1973, p 185).

7.5. Kenya

The rainfall in the Kenya highlands varies considerably with altitude, and because of the reduced temperatures and evapotranspiration rates with increasing altitude, a given quantity of rainfall may be more effective than at a lower altitude. Substantial areas receive between 1200-1500 mm. For example much of Nyeri District, to the north of Nairobi, comes into the humid zone. The area populated by the Kikuyu people, who live mainly in Nyeri, Kiambu and Fort Hall Districts, is one of the most densely settled regions in Africa. By 1962 the population density was already 315 km-2, and Kenya's population increase rate of over 4% a year, the highest in the world, means that the population will double in less than 20 years. However, some people are moving out.

The following description of Nyeri District is taken from de Wilde (1967, p 33 on). The altitude varies from about 1200 m in the south-east, to roughly 2300 m on the slopes of the Aberdare Mountains to the west, and the rainfall varies from about 900 mm in the south-east to about 1800 mm in the south-west. But much of the District lies between about 1500 and 2000 m altitude, and receives between about 1000 - 1500 mm rainfall in the two rainy seasons - the "long rains" in March - May, and the "short rains" in November-December. Most of this area is described as the kikuyu grass ecological zone, and has a high potential for crop production. The principal staple food crops are maize and beans, usually grown mixed. Both sweet and Solanum potatoes are also widespread, with a wide range of other crops including vegetables and fruit. The main cash crop is arabica coffee, but tea and pyrethrum are also grown in the higher areas.

In the late 1950's and early 1960's one of the most remarkable revolutions in the history of African agriculture took place in some of the highland areas of Kenya. This came about as a result of the Swynnerton Plan which set out to reorganise and increase output and profitability from the African farming area. By the mid 1950's, increasing pressure on the land had led to soil exhaustion, erosion, fragmentation, declining crop production and often poverty and hunger in most of the heavily populated areas in Kenya. Many of the men (estimated at 29.4% in 1962) had left their home areas to work either in Nairobi or in large scale farming areas. On these farms they gained considerable experience of modern farming methods and potentials.

From 1954 the government of Kenya began to implement the Swynnerton Plan for the development of smallholding agriculture. This Plan placed a strong emphasis on expanding cash crop production under careful controls to ensure good land and crop management, high yields, quality and profitability. In addition to the emphasis on cash crops, a radical programme of land consolidation, registration, and planning farm layouts was put into effect.

Once the farmers in an area had agreed to consolidate and register their holdings, accept a new-farm layout, had bench-terraced 0.2 ha of land and dug holes for coffee planting, they could obtain coffee seedlings. These were manured, mulched, pruned and sprayed against pests under the supervision of the coffee instructors, and high and profitable yields were obtained. Initial costs of coffee planting were paid off in four years, and the surplus of current income over cash expenditures on mature coffee grown by a selected sample of farmers averaged £420/ha (about US $1260) in 1962/63, and £408/ha (about US $ 1200) in 1963/64, respectively. This was equivalent to a return of Shs 4.54 (about US$ 0.65) and shs 4.16 (about US$ 0.60) respectively per hour of family labour devoted to coffee. The farmers obviously considered the incentive to grow coffee very attractive at this time, as the number of growers increased from 7,886 in 1960 to 22,512 in 1963, and continued rapid expansion took place. A similar expansion occurred in tea and pyrethrum production, in areas suited to those crops.

It is interesting to note that a considerable number of farmers were willing to put substantial labour and cash outlays into planting these crops knowing little return would be obtained for 3 or 4 years, in the expectation of eventual profits.

de Wilde (1967, p 49) continued:-

> "In many respects the most remarkable phenomenon has been the rapid development of dairying with cattle of European breeds, principally Guernsey and Jersey".

Farmers who had had their holdings consolidated and planned and who had fenced paddocks were assisted to purchase "grade" cattle and to manage them for intensive milk production. The milk was marketed through cooperative societies which increased their sales ten-fold between 1960 and 1964, when over 5m l were marketed, mainly to Nairobi. In addition to the regular cash income received, the rapid expansion of production indicated that the farmers found dairying highly profitable.

One study indicated a net cash income per cow per year of US $ 55-64. They were also able to use some of the milk (probably about a third) for home consumption. These highly intensive farms, despite their small size, were also labour-intensive, and many of them used substantial amounts of hired labour.

7.6. Synthesis

This transition zone between a unimodal and a bimodal rainfall distribution, and between savanna and forest, is well suited to a wide range of crops, both annual and perennial. In West Africa the 'yam belt' is mainly found in this zone, together with cassava, maize, sorghum, rice (both rainfed and swamp), groundnuts, plantains (starchy bananas), coffee, citrus, etc. Due to widespread trypanosomiasis cattle are less common in this zone than in the drier zones, but goats and sheep are common.

In East Africa, where the rainfall distribution is mainly bimodal, bananas are an important staple food at the middle altitudes in Uganda, northern Tanzania and Rwanda, together with sweet potatoes, cassava, maize, Phaseolus beans and some swamp rice. Robusta coffee is the main 'cash' crop, and some tea, sugarcane and pineapples are also grown. Many different fruit trees are planted, including citrus, loquat, avocado, breadfruit, jakfruit, etc.

At the higher altitudes maize is the dominant cereal, with Phaseolus beans, sweet potatoes, Solanum potatoes, bananas, arabica coffee, tea, pyrethrum and a wide range of vegetables and other crops.

Although trypanosomiasis is present in some of the low and medium altitude parts of the zone in East Africa, it is less widespread than in West Africa, so cattle, sheep and goats are widely distributed. The climate is excellent for pasture, so there has been an impressive development of highly productive small as well as larger-scale dairy farms in the Kenya highlands, with European and European-crossed dairy breeds, and with some extension into Uganda.

Although there can be problems with annual crop production in this zone, because neither rainy season can be relied upon to provide enough rain for a crop in some areas, in general the zone has a high potential for both crop and animal production, particularly at the higher altitudes and on the better soils. In West Africa it does not yet appear to be too heavily populated in most areas, though populations are probably increasing rapidly, partly by in-migration. In East Africa, the highland areas in the zone are some of the most heavily populated regions in Africa. Although there have been some impressive developments of highly intensive farming systems, particularly in the Kenya highlands, there appear to be dangers of holdings becoming sub-divided and fragmented into uneconomically small areas which may not be sufficient to provide subsistence, let alone a reasonable income. Soil fertility deterioration and erosion also pose a constant threat.

Chapter 8. CONCLUSIONS

8.1. Land Use and Farming Systems

The vast majority of the people of Africa still live in rural areas, and are directly dependant on the land for their living. The data quoted in this study show that although the 45 countries of the African savanna contain an enormous variety of environments and peoples, there are remarkable similarities in the farming systems throughout the continent. With the exception of an almost negligible number of larger-scale 'commercial' farms the great majority of African farmers cultivate 0.2-0.4 ha of subsistence food crops per person. Where crops are also grown for sale, an additional 0.2 - 0.4 ha per person may be cultivated, particularly when oxen are used for ploughing.

Since the number of man - equivalents (ME) often seems to be about half the number of people in a family, the area per ME is about double the above. Thus the lower limit for subsistence appears to be about 0.2 ha per person, or 0.4 ha per ME, giving roughly 200 kg of grain or the equivalent in other foods in an average year. When simple mechanisation such as the ox-plough is used, the upper limit seems to be an average of about 0.8 ha per person, or 1.6 ha per ME. With an average family size of about 5 - 6 people, this gives a cultivated area per family of about 1 - 4 ha (Some extended families living in the same compound are considerably larger). Seasonal labour bottlenecks appear to limit the cultivation of larger areas. These will be discussed later. Mean farm size per family appears to vary from about 3 - 10 ha or more, but in areas where population pressure is low and shifting cultivation or its variants are still practised, farm size may not mean much. Farmers use the land that they need, and other land is held communally. While accurate statistics over wide areas are difficult to obtain, it seems likely that perhaps 95% of African farms come within the above limits.

Although there are many variations, the basic farming pattern follows the 'ring' layout described on p 8. This remains true whether people live in solitary homesteads or in villages. The land immediately around the homestead or village is used for 'garden' crops, the surrounding area is cropped more or less continuously, often without much attempt to maintain fertility, and if ample land is available, the land further away is cropped for 2 - 4 years and then left for a few years under fallow. If land is scarce, all the land may be cropped in most years with an occasional fallow year. In this case, depending on inherent soil fertility and the availability of livestock, efforts may be made to manure more of the land..

Livestock ownership is variable, but it appears that a high proportion of farmers keep a few goats and/or sheep, perhaps averaging about 2 - 6 per farm, and some poultry. A similar average number of cattle are owned by a smaller proportion of farmers, depending on the incidence of trypanosomiasis and other factors. A few farmers keep 1 or 2 pigs, and in the drier areas some farmers keep donkeys, horses, and camels. Livestock are not usually closely integrated into the farming system, being mainly grazed on communal grazing lands, often by herdsmen from a different tribe. They may graze stubbles and crop residues after harvest.

The remarkable similarities in the farming systems practised in the same bioclimatic zone throughout Africa have already been discussed under each bioclimatic zone. These similarities suggest that changes and improvements being practised by farmers in one part of a zone might be of interest to many farmers in the same zone in other parts of Africa, but only if the necessary conditions are fulfilled. These conditions will be considered later.

African farming systems have evolved over many centuries in response to particular sets of environmental conditions, and they are constantly changing in response to changing circumstances. They have usually provided the minimum level of subsistence food production needed for survival in most years. Until comparatively recently, in those areas where communication and transport facilities were virtually non-existent, there was little advantage in producing a surplus for sale or exchange outside the community, because there were so many difficulties in marketing it, so communities lived at a subsistence level. Some insurance against the risk of crop failure was provided by storing grain for a few years, or by planting cassava surplus to immediate needs. Surplus grain could also be exchanged for livestock in good years, and the livestock could again be exchanged for grain if times became hard.

Richards (1939) has described the security within the community built up by small reciprocal gifts of food and by fulfilling other traditional obligations. Where pressure on the land was low these measures appear to have been sufficient to allow survival, though competition between tribes for resources, particularly land, appears to have caused conflict from early times, as it has elsewhere in the world. Also, in the drier areas, runs of unusually dry years are remembered in most communities as having caused famine. The response seems often to have been for the whole community to move to another location where food was thought to be more readily available. Famine was also sometimes caused by the depredations of locusts, rodents, and other plant or animal pests and diseases. Both human and animal diseases are particularly severe in the higher rainfall low altitude areas, and it seems possible that they may be at least part of the reason why so many people seem to wish to live in the arid zones, despite the risks of drought, or in the highland areas.

8.1.1. Fragility

Because the soils of most savanna regions are low in inherent fertility (see Chap 2), and the rains are uncertain, particularly in the arid and sub-arid zones, the majority of African farming systems are relatively fragile. As described earlier (p 40) Higgins et al. (1982) have identified the arid and sub-arid regions of Africa as particularly at risk from excessive pressure of people and livestock on the land at the present low input levels. Other heavily populated areas such as the whole of northern Nigeria, the highlands of Ethiopia, Kenya, western Uganda, Rwanda, Burundi, eastern Zaire and Malawi are also identified as at risk at low input levels.

Although there have been substantial changes in some of these systems, and input levels have risen, for example as described for the Kenya highlands (p 99), It is not clear whether farming systems will change and intensify fast enough to keep pace with population growth and to allow reasonable standards of living in many of these areas. As population and livestock pressure increase, in many areas the result has been that soils become more impoverished, and growth of both crops and natural vegetation are reduced, exposing the bare soil to erosion. Farmers respond where possible by replacing the more valuable grain crops with crops like cassava, which can produce a crop on quite poor soils. Eventually crop yields may reach a fairly steady state at a relatively low level, which may or may not provide subsistence for the inhabitants. Further losses of topsoil, particularly where the soils are shallow, may cause abandonment of cultivation altogether. (Ruthenberg, 1980, p,11.).

It has been suggested that this deterioration in the farming systems can be hastened by over-rapid adoption of a cash crop such as groundnuts or cotton (eg. Ruthenberg 1980). However, the experience in Mali (p 112) indicates the opposite. There the adoption of cotton allowed farmers to invest in inorganic fertilizers and animal traction, including the making and carting of manure to the fields. The result was that the farmers themselves developed an intensive permanent cultivation system on relatively poor soils with some of the highest yields and gross margins which I have found in semi-arid Africa. Thus it is clear that the direction in which farming systems go under increasing population pressure depends more on the available resources and the farmers response to their problems than on other factors. While many complicated interactions are involved, and it is dangerous to over-simplify a very complex situation, it does seem clear that different farmers, and even communities, react in different ways to pressures. It is well known that there are individual differences between farmers with similar resource levels, particularly in management ability (fig 14).

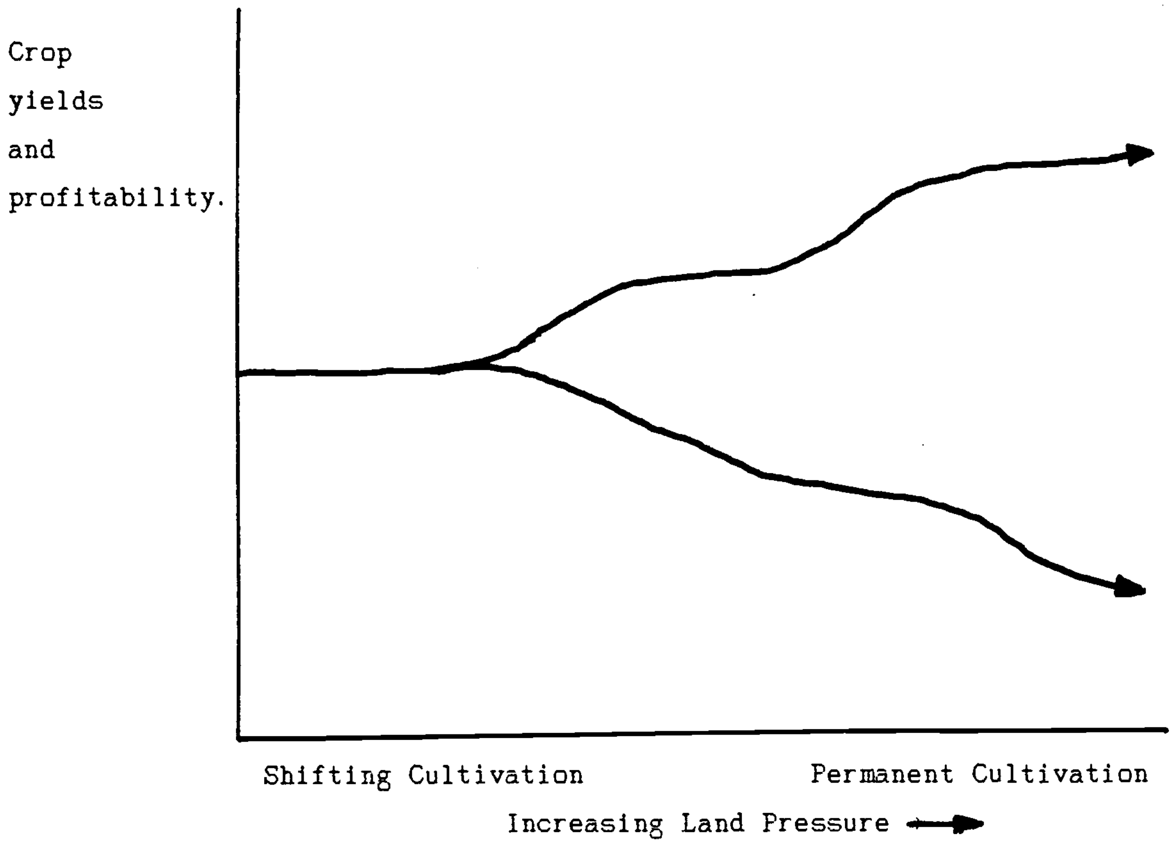


Fig 14. Possible directions in which farming systems may evolve under increasing population pressure.

Some farmers will respond to pressures by experimenting, innovating and managing their resources more efficiently, while other farmers are much slower to do this, though they may follow along when the leaders have shown the way. Where conditions are very hard, or the range of options is severely limited, it may be difficult for any farmers to make much progress, and this is where government action may be needed to improve conditions.

8.1.2. Motivation

What causes farmers to change their systems? Obviously economic pressures in various forms play a large part. As outlined above, land pressure may be one of the most important, but seasonal labour shortages, and plain poverty also affect decisions. Many social pressures also affect farmer' actions, as most people are reluctant to stand out against the general will and ethos of the community, particularly in strongly traditional societies. Norman et al.(1981, p 19) have summarised some of these community norms, structures and beliefs.

8.1.3. Incentives

Like people anywhere, farmers respond to incentives, and in general the magnitude of the response depends on the size of the incentive. (Eicher and Baker 1982 have reviewed this topic exhaustively). Many of the frustrations of research and extension workers from colonial times onwards, when farmers did not accept apparently improved technologies, were due to two reasons. First, many of the technologies did not fit the farmers' needs, and second, the improvements did not provide sufficient incentives to farmers to change. (e.g. see Carr 1982, Anthony et al. 1979). This may be the most critical issue for the improvement of African farming systems, and yet it seems to receive remarkably little attention from policy makers and others. In particular, almost no research results have been found which indicate the minimum levels of the incentives which are required to induce farmers to accept various innovations. It appears that this could be a research topic which should receive increased attention, together with risk analysis, perhaps particularly in the farming systems research programmes which will be discussed in a later section. Care will be needed in conducting the research, particularly where crop prices levels are to be varied.

8.1.4. Risk

Although risk-aversion can be expected to be important to people living near the margin of survival, and it is undoubtedly true that savanna farmers are generally reluctant to take undue risks, little research appears to have been done on this important topic. The priority which farmers normally place on safeguarding their food supplies, is a response to risk, as is their cautious approach to new, often unproven technology. The purchase of livestock as a 'bank on the hoof' may be another response. But where the incentives outweigh the risks in their perception, there is a large body of evidence that savanna farmers will make rapid and substantial changes in their systems.,(e.g. see de Wilde 1967, Richards 1973, Anthony et al 1979 etc).

8.1.5. Modernization

The process of opening up what were relatively closed traditional societies has been going on for many years at varying rates in different parts of Africa. This complicated process, assisted by many factors, of which communications, education, urbanization, and external trade are but a few, has often been disruptive in its effects on fragile traditional societies. Although modernization has brought increased material benefits to some, many are still caught in the vicious circle of poverty, malnutrition and sickness, with less support than before from the extended family and the community. Some of the worst-off may be the landless city slum-dwellers, as the possession of a piece of land usually provides some insurance for rural people, however poor.

8.2. The Land

Land and people are almost the only resources that many savanna countries possess, and the interactions between them make up farming systems. Land use practices are of critical importance to the long-term future of all countries, yet they often seem almost totally neglected by many governments. While governments may be overwhelmed by a multitude of problems all needing attention at the same time, and they may have considerable difficulty in making much impact on rural life, their allocation of resources sometimes seems questionable. Instead of attempting to guard, conserve, and build up what is their main productive physical resource, the land, they sometimes almost seem to encourage its exploitation, either by unwise policies such as encouraging large-scale mechanized land clearing or by almost total neglect of simple soil conservation measures.

Although governments often pay lip service to increasing agricultural production, and they employ large bureaucracies in their agricultural services, their policies and resource allocations seem mainly directed towards the needs of the wealthier section of the urban population, rather than the rural poor (e.g. see Carr 1982).

8.2.1. Land Tenure

Traditionally, when population pressure over much of Africa was comparatively low, most African societies practised various types of communal land tenure, where the family head had the rights of use of a particular area of land for as long as he needed it. Legal ownership of the land was usually held by governments, but allocation of the use of land at the local level was done by chiefs or other traditional land authorities. This right of use would normally be passed from fathers to sons, sometimes to the eldest son, but often the land was divided amongst the sons. This traditional system remains the basis for land tenure in most savanna countries, and Norman et al (1981, p37) have suggested that it is the main reason for the relatively equitable distribution of land in most parts of Africa. Land has a deep religious and mystic significance in most African communities, in addition to being the main source of security.

As pressure on the land and 'modernization' increase, and land becomes a scarce resource, land use tends to become more individualistic, and borrowing or renting the use of land become widespread. Eventually land is bought or sold like any other commodity, and many governments have started granting legal land titles to the owners. In parts of Uganda, particularly Buganda, land titles were granted to certain chiefs in the early years of this century, on the basis of multiples of square miles (1 square mile = 2.59 square kilometres). Fortunately the traditional tenure systems continued as far as the farmers occupying these 'mailo' lands were concerned, and rents were held down at a low level, so there was not too much disruption of the traditional society (Richards 1973). In those countries where large areas of land were alienated to foreigners, considerable hardship and friction was caused as pressure on the land increased (Weinrich 1975).

In some societies with heavy population pressure, fragmentation became widespread and severe. For example, fragmentation was a serious problem in parts of the Kenya highlands, in south-west Uganda, and in the Sine Saloum area of Senegal. Although it may be argued that some farmers could gain certain advantages from a degree of fragmentation, if it enabled them to have the use of a variety of different land types suitable for various crops, in general farming efficiency seems to decline on severely fragmented farms. The willingness of farmers in parts of Kenya to consolidate and replan their holdings appears to support this view. In particular, fencing for small-scale dairying would probably be uneconomic on severely fragmented farms. Also consolidated farms should be easier to work (e.g. see de Wilde, 1967, and Faye and Niang 1977).

8.3. Labour

Many economists, including Mellor (1984), have pointed out that smallholder labour productivity in Africa appears to be considerably lower than in Asia. There seems little doubt that a major problem, particularly in semi-arid Africa, is the marked seasonality of farm work. In his detailed discussion of labour issues, Norman (1982) has emphasised the weeding bottleneck as a particularly severe one in many farming systems. In the drier areas, the critical timing of land preparation and planting may cause bottlenecks, while with modern technology and increased yields, harvesting of certain crops may become a bottleneck (Delgado 1979). Definitions of what is mans' work and what is womans' work can sometimes cause bottlenecks, particularly since women are usually heavily involved in many household tasks such as fetching water and firewood, pounding of grains and cooking. But with the introduction of 'cash' crops and changes in the farming systems the definitions of mans' and womans' work do seem to change over time. Farmers would normally be expected to seek new technologies which would reduce their own production constraints, and this does seem to happen slowly.

8.3.1. Mechanisation

Mechanisation is not traditional throughout most of Africa. Only in Ethiopia has animal traction been widely practised for many hundreds of years. As outlined above (p 86) Anthony et al (1979, p140) suggest that with the exception of Ethiopia, ox-ploughs were first introduced into tropical Africa around 1910, and Teso District in Uganda was one of the first locations where farmers adopted them. Animal traction also spread in Senegal, and in limited areas in a number of other countries, such as Gambia, Mali, Burkina Faso, Nigeria, Kenya, Tanzania, Zambia, Malawi, Zimbabwe, Lesotho and Botswana. But in most of these areas its spread seemed to be linked to the spread of a new 'cash ' crop, usually cotton or groundnuts, or maize in southern Africa. Elsewhere farmers often seemed to be slow to adopt it. While farmers operating near the subsistence level might have had some difficulties in finding the cash to buy a plough and oxen, and Starkey (1986) suggested that Senegalese and Gambian farmers used donkeys and light cultivators for this reason, it appears that farmers who already owned cattle should not have had too many problems. They could have sold a cow to buy a plough or cultivator.

But there were indications from the Mali farming systems project (p 111) that farmers who were unable to achieve food self-sufficiency did not consider it worthwhile to use animal traction until a new package of maize, manure and fertilizer was introduced, even though they already owned cattle and a few ploughs. I think this supports the principle that mechanisation is only valued by farmers in so far as they perceive that it reduces their constraints, including drudgery, and increases their land and/or labour productivity and profit margins. If the weeding bottleneck mentioned above is a serious constraint, it is interesting to speculate why farmers seem generally to have been slow to adopt ox-weeders, even when incentives in the form of loans and subsidies were offered to them. (An exception may be Senegal, where the sine houe toolbar was widely adopted).

Part of the reason may have been the lack of a satisfactory seeder for row planting, but even where crops were accurately planted in rows little inter-row weeding with oxen was done. Possibly farmers found too many difficulties in training their oxon properly, or considered that possible damage to their crops outweighed any reduction in the weeding bottleneck. Farmers' reluctance to adopt wheeled tool-carriers, even when they were heavily subsidized (well documented by Starkey 1987), is also of considerable interest.

On the other hand, there are many examples of farmers' enthusiasm for tractor ploughing, and their willingness to pay quite large sums of money for this operation. Where the tractors were owned and operated by the larger farmers, as in the central rainlands of the Sudan, or in parts of Kenya and Zambia, they seem to have been incorporated into the farming systems, but the total number of farmers involved is very small. Also sometimes tractor owners or contractors would hire them out to other farmers, to the profit of both. But the evidence appears to indicate that in general government-organised tractor hire schemes or group farms have not been able to operate economically without heavy subsidies. (e.g. See Carr, 1982, de Wilde, 1967).

In most countries the first parts of the agricultural production system that are successfully mechanised are usually various aspects of crop processing, particularly grain milling, and water pumping. The spread of small village grain mills, mainly hammer-mills powered by small petrol or diesel engines, or if electricity is available, by electric motors throughout Africa is impressive. This new technology seems to have spread with little government or external support.

There appears to be increasing interest in the small-scale mechanisation of other aspects of crop processing, particularly decortication (IDRC .....) and threshing. Pumps for small-scale irrigation also appear to be becoming popular in some areas where crop prices can justify their capital and running costs.

8.3.2. Chemical Herbicides

An alternative way of reducing weed competition is by the use of herbicides. Although herbicide use can be complicated, particularly where mixed cropping is practised, and prices are often high in relation to the prices which farmers can obtain for their crops, their use on certain crops in particular farming systems does seem to be spreading. The need for additional on-farm research on herbicide use will be discussed in a later section.

8.4. Capital

Shortage of capital is a widespread constraint in savanna farming systems. Traditional subsistence cultivators invested little capital in their farms. Their possessions included a few hand tools, home-made houses and granaries, and some livestock. Even the acquisition of a plough and a pair of oxen is a major item of capital expenditure, which appears to be beyond the reach of many of the poorer farmers. Wealthier farmers, on the other hand, who possess several cattle, have a considerable amount of capital tied up in livestock. There appears to be an increasing trend to purchase livestock using any profits from crop sales (Haswell 1975, Norman et al 1981). The livestock serve as a 'bank on the hoof', and an insurance policy to be cashed in if there is a need to purchase food, or fulfil social obligations, as well as a source of milk, meat, hides, skins, power for animal traction, and manure for the land (e.g. Delgado 1979). However, if herdsmen from another tribe such as the Fulani are employed to herd the cattle, the milk may go to the herdsmen, and the manure may not be used.

With increasing modernization and production for the market, gradually more inputs such as fertilizers, sprays and machinery may be purchased, but capital investments in the form of fencing, water supplies etc. tend to remain minimal for all but the wealthiest farmers. In many areas the poorer farmers may be so short of money that they are forced to sell a substantial proportion of crops such as groundnuts soon after harvest, when prices are often low, in order to obtain cash, and then to buy food or seed when they become short later in the season at much higher prices. In general it appears that farmers are more willing to apply inputs such as fertilizers or insecticides if they are provided on credit, the cost being deducted when the crop is sold, but Eicher and Baker (1982) have questioned the real need for credit in many situations.

In recent years International Agricultural Research Centres, donors and others appear to have become more conscious of the extreme poverty of many small farmers, so the 'low input strategy' has been widely promoted. While this strategy may be appropriate for subsistence production, it may be counterproductive where profitable marketing opportunities exist. For example, if a high-value crop is introduced which has an assured market and which will give a high gross margin with few risks if substantial purchased inputs are provided, usually even the poorest farmers will wish to maximize their profit by applying the optimum inputs, usually with credit. In such cases it makes no sense to try to implement a low-input strategy across the board.

8.5. Management levels

Although surprisingly few factual data seem to be available, it is clear that there are wide variations in levels of management between individual farmers, as is to be expected. (e.g. see Haswell 1975, Matlon 1977, Richards et al 1973) Although the decision-making process in extended families is complicated and often difficult for outsiders to understand, there is an increasing tendency for the traditional large families to break-up and separate into nuclear families. Although these smaller families may have greater freedom to innovate, they are often limited by resource constraints. Management levels often seem to depend heavily on the past experience of the farmers. Farmers who have worked on modern commercial farms often seem to have learned many managemement skills (e.g. Anthony et al 1979, de Wilde 1967).

However, while the majority of smallholders probably try to optimize their use of the limited resources available to them, within the limitations of their environment and background, poverty, risk, and other severe constraints do appear to slow down smallholders adoption of some new technologies. For example, simple soil and water conservation practices would provide long term benefits in farm productivity, but because their short term costs may appear to outweigh their short-term returns, their adoption rate is often very slow. Similarly , the control of livestock numbers and the management of grazing in communal grazing areas could be expected to give substantial long term returns to the livestock-owning community, but because the short term gain may be reduced it is seldom practised.

8.6. Markets, Prices and Inputs.

Although many smallholders still seem to maintain food self-sufficiency as their first priority, nearly all of them are involved in some way in the market economy This may consist mainly of selling a 'cash' crop to a local marketing agency, or of buying or selling food crops in a local market. Many governments set prices to farmers for 'cash' crops, and they may also set fixed or minimum prices for certain food crops. Prices for 'cash' crops are often set below realistic market levels, or taxes may be deducted from them, to assist in government revenue collection. These reductions can have serious effects in reducing farmers' incentives to produce. (e.g. Carr, 1982).

In the case of surplus food crops, governments have often been unsuccessful in administering fixed or minimum prices. Difficulties sometimes appear to be caused by attempting to fix prices at unrealistic levels. Also in a mainly subsistence economy, where only a small proportion of total production comes onto the market, small changes in production can lead to large changes in quantities coming onto the market. For example, in Mali there were deficiencies in food grains up to 1984, so the government set the minimum grain price at a fairly high level to stimulate production. The good rains in 1985, together with food aid, made up the deficit and filled the available storage space. A second good season in 1986 together with a continued high price led to a substantial production surplus. Private traders lowered their prices to about half the government price, but government storage space was soon filled, so the price dropped to the market rate. Farmers who had invested in fertilizers and other inputs in the expectation of receiving the goernment minimum price experienced considerable difficulties in repaying their loans. At the same time food aid was still coming into the country, and this contributed to the fall in market prices. It seems likely that the farmers reduced their production the following season.

This problem of surpluses seems one of the most difficult to handle, particularly for land-locked countries like Mali. It appears that the delevelopment of efficient, low-cost transport facilities should assist in the disposal of surpluses either within the region or on the world market. At the same time, improved transport would allow inputs to enter at competitive prices.

8.7. Support Systems and Development Projects.

8.7.1. Agricultural Research.

In the past, agricultural research in the African savanna has been heavily weighted on the side of 'cash crop' research on research stations. There were reasons for this. When populations were still fairly small, and population pressure on the land was low in most areas, overall food production problems were not particularly severe. The widespread fallow-farming systems, mainly based on shifting cultivation, were reasonably stable. Local food shortages due to the failure of the rains, or to pest or disease outbreaks, did occur from time to time, but food deficits could be corrected by transport of surpluses from other more productive areas. This was sometimes done by commercial traders but governments would act to supplement their activities when necessary (e.g. Allan 1965). Therefore, since food production was not generally perceived as a problem, it often did not receive priority research attention.

Instead the new 'cash' crops, especially cotton and groundnuts, which had a number of production problems, particularly pests and diseases, received most of the research attention. For example Wrigley (1959) has documented the vital role which smallholder cotton production played in the early years of this century in Uganda, both in providing a cash income for farmers, and for building the whole economy of the country.

There were, however, exceptions. Maize and cassava breeding received considerable attention in East Africa from the 1930's onwards, and maize research was also pursued in Southern Africa, with good results. A large increase in research budgets and staffs took place in many countries in the 1950's and 1960's, and many food crops received some research attention. Carr (1982, p 73) has questioned whether some of these programmes were as effective as they should have been, and he makes the following comment:

> "An unfortunate result of the lack of impact of research programmes in a number of countries has been a decline of interest, support and attention for their work on the part of government. Low priority is given to the financial needs of the programme, there is

little overall control over strategy, and research workers often find that the only path to promotion is to leave research altogether. This is unfortunate as the continent faces increasing pressures of various kinds which make the need for technically, managerially and economically viable innovations more urgent than they have been in the past. This requires both fundamental research and a greatly increased level of field experiments if the problems of increasing production, particularly in the drier areas, are to be solved. The difference between what is required and much of the work of the past depends upon the level of understanding of the real problems of the small farmer and the appropriateness of what is offered to his actual circumstances"

8.7.2. Research Planning.

In view of the urgent nature of the agricultural problems which are accumulating throughout the savanna, and the limited resources, includig trained manpower, available for research, it appears essential to ensure that none of these resources are wasted. This requires a rigorous determination of priorities and operational procedures. Although the problems of savanna agriculture are many and varied, if it is accepted that the overriding problem is one of deterioration in land use practices, and the breakdown of smallholder farming systems, throughout the savanna, this has certain implications for research.

8.7.3. Farming Systems Research.

One way of looking at research needs as they affect the farmer is to consider them in the context of farming systems research (FSR).

This concept has been fully described by others, such as Collinson(..........), Zandstra (1982) and Norman (1981), so it will not be considered in detail here. It is defined here as including both on-farm research and on-station back-up component research.

8.7.4. On-Farm Research.

On-farm research can be criticised as being too location-specific and therefore expensive for widespread application. While it is true that every farm is different and therefore logically on-farm research would need to be done on every farm, in practice, as in every other type of research, priorities have to be established and choices made When the planning process indicates that on-farm research can make a useful contribution and is a wise use of resources, it needs to be properly planned with full farmer involvement, as an integral part of the whole research and extension programme. Experience in many countries indicates that if this is done, and the research is carefully and thoroughly carried out, it can often make considerable contributions towards:-

1) Designing and testing improved technologies and systems that are profitable and acceptable to farmers.

2) Reflecting back farmers' real problems and constraints to on-station research workers, and encouraging them to become involved with farmers with the aim of alleviating their problems.

3) Strengthening the linkages between farmers, researchers, and extension workers, providing proven technologies for extension workers to test with wider groups of farmers, and if successful, extend into larger recommendation domains.

4) Strengthening linkages between farmers, research and extension workers, and policy makers,so that viable choices for improved agricultural policy options are presented to governments and others.

8.7.5.On Station Research.

The term 'on-station backup component research' is used here to include all types of research, sources of knowledge and improved technology off-farm, which can be expected to contribute to farming systems. It is suggested that these types of research should be mainly identified and tested through the on-farm research programmes, and recommended technologies should be subjected to regular rigorous analysis of their cost-effectiveness by FSR researchers.

Any country which wishes to develop its agricultural potential over the longer term needs to have some agricultural research capacity, but this will not be discussed in detail here.

8.8.Future Prospects.

In general the overall potential prospects for agriculture in the savanna can be promising. Much of the area enjoys an excellent climate for crop and animal production, and even the drier parts have a potential for carefully designed and executed farming systems and for irrigation where water is available. Although, as outlined above, many of the soils are relatively fragile, with ordinary good farming practices most of these soils can be made to produce abundantly over an indefinite period.

The FAO agro-ecological zones project (Higgins et al 1978) has estimated that for the whole of sub-Saharan Africa only about one sixth of the potential rainfed land is in use at present. Also the potential irrigable land is estimated at 6 - 8 times the present irrigated area. Even at a modest intermediate level of inputs, involving improved varieties, simple crop and animal protection measures, some use of fetilizers, simple field tools, some soil conservation measures and some supplementary power, Africa as a whole should have no problems in feeding iself, and even exporting a considerable surplus. But some countries, particularly in the arid and sub-arid zones, nay have difficulties in feeding themselves, and these countries will probably need to import food from neighbouring countries (Bunting 1987).

At high input levels it is thought that Africa could feed the population of the whole world, if necessary. Therefore the potential is enormous, but the present production falls very far short of the potential, and appears to be declining in many areas. It is the thesis of this paper that in the savanna this decline is due to the failure of most farming systems to change and adapt sufficiently rapidly to changing conditions, particularly increasing population pressure. This failure has led to a particularly serious decline in soil productivity.

Therefore there is nothing inevitable about the overall decline in savanna farming systems, but without urgent, intelligent, and sustained action by all concerned, this decline can be expected to continue, and then the outlook becomes very gloomy. Africa is littered with poorly planned and executed agricultural projects, which achieve very little and often eventually fail completely. Instead of publishing the results and trying to learn from these failures, they are often conveniently forgotten, so that the same mistakes may be made in the same area by a similar project within 5-10 years. Therefore it is proposed that the following urgent action needs to be taken by governments and international agencies working together, even though it is fully realized how severe are the constraints and pressures under which governments are working. Also some governments already have excellent programs operating.

1) Land Use Management and Conservation.

Define the extent of the problem and the most urgent areas needing attention. This could be done by setting up a national agency for land use management and conservation, if this does not already exist. This could collaborate with the FAO Agro-ecological zones project to extend and test the results of the above project within each country, particularly to define critically at-risk areas. This agency should also have the capability to conduct detailed studies to design improved land management systems for specific areas such as watersheds with special problems, resettlement areas, irrigation schemes etc.

2) Farming Systems Research.

Establish a strong farming systems research capability to work with farmers, extension workers and others in the areas identified as needing urgent attention.

3) Communications and Markets.

Take all possible action to improve roads and other communication channels between the affected areas and national, regional and international markets, and encourage traders and other agencies to provide efficient markets and input supplies.

4) Incentives.

While encouraging commercial trading activities, to seek ways of establishing adequate incentives, particularly in the form of minimum prices for agricultural products.

These incentives should correspond with those identified by the FSR teams as most likely to correspond with farmers' needs and assist them to transform their farming systems into productive, sustainable forms.

An important part of this would have to be plans for the storage (preferably on-farm), transport and marketing of possible surplus production, to allow minimum prices to be supported.

5) Training

Excellent training facilities would need to be established or strengthened, preferably at national level, but failing this at regional or international level, to train land-use, FSR, extension, and other staff to carry out the above programmes.

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